THE EFFECT OF ANIMAL MATURITY AND FAT DISTRIBUTION UPON THE ACCEPTABILITY OF IRRADIATED GROUND BEEF

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INTRODUCTION

Today one can see beyond a doubt that the Atomic Age has surely decended upon the realm of mankind. The discovery and recent development of atomic energy has truely revolutionized man's thoughts. Man has considered both the beneficial and devastating effects of this newly harnessed energy. It was truely inevitable for atomic radiation to become involved in one of man's oldest conquests, i.e. the preservation of food.

The preservation of meat via. radiation was considered to have sufficient merit that the Quartermaster Food and Container Institute was authorized to undertake and sponsor numerous contracts concerning the subject. The purpose of such experimentation was to encounter and try to solve the many problems which arose from the irradiation of meat. It was fully recognized that any adequate method of meat preservation depends primarily upon the destruction of meat spoilage microorganisms and the naturally occurring meat enzymes. Such a sterile condition of the meat should prevail throughout subsequent storage to allow for safe human consumption. In addition the method of preservation should not alter the organoleptic qualities of the meat to the point that its acceptability is impaired. These are but a few of the problems confronting scientist today with respect to meat preservation via. irradiation.

Before domestic use of irradiation preserved meat can materialize, these questions and others must be answered adequately to remove all doubts from the consuming public's mind as to its wholesomeness. At this time it is believed that levels of irradiation resulting in pasteurization of meat are more desirable than levels of irradiation which results in sterilization of the product. The lower pasteurizing levels of irradiation are adequate to destroy many spoilage microorganisms which might be present in the meat, but still remain acceptable to a consumer. These low doses of irradiation, however, will have little if any effect upon the naturally occurring meat enzymes. These may be destroyed readily by the use of heat in the way of cooking.

Two characteristics of meat which are thought to affect the palatability of irradiated beef are animal maturity and fat content. These two factors are now known to exert some influence upon the acceptability of non-irradiated beef. The meat derived from younger animals is generally more tender. This is considered to be the result of less dense connective tissue and a higher moisture content present in the meat at this stage of maturity. However, it is well known that the advancement of maturity results in the development of a more flavorful product. With the advancement of maturity comes the deposition of intracellular and extracellular fat. This is related, within certain limits, to the preferred flavor of beef. With these facts in mind, carcasses from animals of different levels of maturity containing different quantities of fat were used to determine their effect upon the acceptability of irradiated ground beef.

Questions of equal importance to be answered are as follows: (1) what irradiation level is optimum, (2) what is the optimum storage temperature and (3) what length of subsequent storage will be permissable? The work presented here will provide some information from an organcleptic point of view.

REVIEW OF LITERATURE

The practical value of utilizing gamma radiation as a method of cold sterilization to preserve meat and meat products is a very controversial question. Such sterilized food products have shown excellent keeping qualities in the absence of other meat preservation methods. On the other hand, undesirable organoleptic changes occur in meat as a result of the irradiation. The organoleptic factors affected by irradiation are numerous, therefore, each will be discussed independently of the others. This, however, does not imply that each organoleptic factor occurs and reacts completely independent of the others, but rather a possible interaction between them may occur from such treatment.

Color

Hematin pigments which are primarily responsible for the characteristic color of meat are very susceptable to irradiation. The first investigation, of any detail, pertaining to the color changes of irradiated meats was that of Brasch and Huber (1948). They noticed that a purple or brown pigment was produced as the result of irradiating raw beef. Morgan (1957) reported that the myoglobin of meat is irradiation-sensitive and yields pigments of a green color. Fox et al. (1958) stated that the irradiation of myoglobin yields two pigments when irradiated. The first pigment was considered to be desirable due to its red color while the second pigment, being green, was considered undesirable. It was also noted that the green pigment was the primary cause of undesirable discolorization in irradiated meats. The green pigment was identified as sulfmyoglobin which was produced during irradiation. Its formation involved the oxidation of myoglobin by hydrogen peroxide and hydrosulfide arising from the destruction or degradation of sulfhydryl components which are naturally present in meat. Fox and co-workers noted that the condition most favorable for the production of the green pigment was the pH of the meat. By adjusting the pH to 5.3 maximum production of this pigment could be produced. With the pH of meat being 5.6, the conditions for the production of the green pigment therein were favorable. It was further reported by Fox et al. (1958) that no serious discolorization was observed when the extracts or meats were irradiated in an atmosphere void of oxygen. Tappel (1958) indicated that fresh meat irradiated at low levels in the presence of oxygen developed a brownish discolorization due to the formation of metmyoglobin. However, when meat containing myoglobin was irradiated a bright red color in meat was developed due to the regeneration of oxymyoglobin (Tappel 1956). This was given as an explanation for the bright red color produced by the irradiation of fresh meats. Fox et al. (1958) noted that the addition of aldehydes inhibited the production of green pigments while cysteine or other sulfhydryl compounds enhanced its production. Although these two pigments comprise the majority of irradiated meat colors, yellow pigments have been isolated from irradiated meat extracts. These pigments appear to be associated with the breakdown of heme pigments. Pratt and Ecklund (1956) noted that the attractive red color of irradiated ground beef had faded somewhat upon storage for one year at 98° F., but still less fading occurred at 70° F. for the same period of time. Tappel (1957) stated that when precooked meats were irradiated, the normal brown or gray hematin pigments were converted to uncharacteristic red pigments. This unusual color of irradiated cooked meats is undesirable in some respects while desirable in others. Its undesirable effects were shown when the members of the taste panel commented that the degree of doneness was not as they preferred. The bright attractive red color was very desirable and appealing in the raw state. It was further reported that the irradiation of precooked meats converted the normal brown denatured globin hemichrome pigment to a red pigment which is best characterized as denatured globin hemochrome.

Odor

The irradiation of meat brings about the production of an undesirable odor. This odor is quite characteristic of irradiated meat, but the description of the odor is varied. A "burnt" odor was the most frequently used term to define it, although, "wet grain," "cabbage," "biscuit," "wet dog hair" and others have been used in an effort to characterize the odor. Hedin et al. (1959) in agreement with other investigators, revealed that the production of the irradiation odor is directly related to the irradiation dose and repeated exposures. A review of the literature indicated that most of the odor producing compounds fall into three large groups: amines, sulfur compounds and carbonyl compounds.

Morgan (1957) suggested that the destruction of protein is the largest cause of the production of off-odors in irradiated meat. Lawton and Bellany (1954) also obtained an unpleasant odor from various irradiated soluble protein and other amino acids. This was in agreement with the findings of Batzer and Doty (1955) who indicated that hydrogen sulfide, methyl and ethyl mercaptan are the principle causes of off-odors in irradiated meats. These investigators reported that irradiated beef containing high levels of intramuscular fat resulted in less glutathione destruction and less hydrogen sulfide production than beef of low levels of intramuscular fat. Batzer and Doty also found that the glutathione content of meat was reduced by irradiation in both whole and ground meat. It was also concluded from this investigation that the addition of glutathione to meat prior to irradiation significantly enhanced the production of the irradiation odor of meat. Witting and Schweigert (1958) concluded from their results that the oxidation products of methional appeared to give rise to the irradiation meat odor. Witting and Batzer (1957) indicated that acrolein reacts with methyl mercaptan to yield methional which alone is odorless, but upon oxidation develops a disagreeable odor.

Batzer et al. (1957) concluded that compounds from irradiated fat do not directly produce the off-odors of irradiated meat. Meat with a higher fat content did not produce the irradiation odor to the same extent as did leaner meats. Sribney et al. (1955) stated that fat appeared not to be the constituent of meat responsible for the production of off-odors of irradiated meat. This conclusion resulted from the findings that less objectionable off-odors were produced from irradiated pork than from beef, due, at least in part, to the higher fat content of pork. Batzer et al. (1957) indicated that the fat content of meat contributes little to the amount of carbonyl groups produced during irradiation, but that the carbonyl compounds do increase with increasing levels of irradiation. It was the opinion of the investigators that carbonyl compounds may have a possible role in decreasing the irradiation odor by reacting with compounds that do contribute to the odor upon their irradiation. Morgan (1957) stated that when fats are irradiated their natural antioxidants are destroyed and an increase in the peroxide production occurs. Marback and Doty (1956) revealed that less hydrogen sulfide was released from ground beef, irradiated at the same level, when the fat content was 20 per cent as compared with meat containing less than 10 per cent. Sribney et al. (1955) stated that no significant increase in peroxide values was obtained between irradiated pork and beef fats. Hedin et al. (1959) reported that lower peroxide values and higher flavor scores were obtained when raw beef was subjected to intermittent radiation.

Batzer et al. (1959), investigating the effects of preirradiation aging, obtained a decrease in hydrogen sulfide, methyl mercaptans and acid-salt soluble carbonyl compounds when stored at low temperatures for three months. Marback and Doty (1956) reported that the hydrogen sulfide content of irradiated ground beef decreases during storage for at least two weeks if it is frozen and stored at 0° F. prior to irradiation. Sliwinski and Doty (1958) obtained no significant difference in the quantities of methyl mercaptan found in meat 36 hours after irradiation if the irradiated samples had been frozen at 32° F. prior to irradiation. Hannan (1956) indicated that off-odors can be reduced by irradiating meat in a frozen state. He further stated that more improvement can be made if oxygen is also removed. Hannan listed three steps in this combined preparation for irradiation. First, the oxygen is removed from the meat, secondly, the meat is then held at -94° F. for preferably two days and thirdly, the meat is then irradiated at this temperature. Precautions are taken to assure no rise in the temperature of the meat while being irradiated. Hannan pointed out that if either of the first two steps are improperly performed the development of the irradiation odor will occur. Sribney et al. (1955)

reported that irradiating beef at elevated temperatures of 75° F. reduced the peroxide values and increased the free fatty acids, although, there was no effect on the development of off-flavors. Sribney and coworkers also stated that when oxygen was removed from the meat the increase in peroxides, carbonyl compounds or free fatty acids was small when beef and pork fats were irradiated at 2 or 4 megareps.

Hedin et al. (1959) found that when raw freeze-dried beef was irradiated the production of the characteristic odor arose only after the reconstitution with water. In this light, compounds were added to mask or eliminate the odor. Hedin et al. treated the irradiated fraction with sodium hydroxide, mercuric acetate, p-chloromercuribenzoate or N-ethyl maleimide. The addition of these compounds almost completely eliminated the odor thus indicating that sulfhydryl or closely related compounds were responsible for the irradiation odor. The addition of p-chloromercuribenzoate to the meat prior to irradiation greatly reduced odor production. Additions of ninhydrin or 2,4-dinitrophenylhydrazine did not reduce odor formation, therefore, indicating that amino or carbonyl compounds were not responsible for odor production. Erdman and Watts (1957) reported that the odor of irradiated cured meats was improved upon the addition of ascorbic acid. It was noted that with traces of copper present in the meat ascorbic acid may accelerate the oxidation of fats, but could be eliminated by combining ascorbic acid with certain commercial smokes and various copper complexing compounds. The application of sodium ascorbate in the presence of nitrite also gave odor protection during irradiation followed by brief storage periods. The use of activated carbons has been shown to effectively reduce the intensity of irradiation odor in beef (Tausig and Drake, 1959).

Flavor

The effect of irradiation upon the flavor of meat is another of the organoleptic factors having decreased acceptability. A variable flavor preference exists among the meat of different species when subjected to the same level of irradiation. Sribney et al. (1955) reported that less objectionable off-odors and flavors are produced in irradiated pork as compared with beef. Pearson et al. (1958) stated that precooked pork irradiated at 2.79 megarads exhibited less adverse effect than that of beef, chicken and veal. The Quartermaster Food & Container Institute (1958) also reported that beef was usually less acceptable than pork and poultry, while veal was intermediate in acceptability. Kirn et al. (1956) indicated that smallest flavor changes in irradiated meats occurred in pork, lamb and chicken, respectively. These findings encouraged Sribney et al. (1955) to state that fat appears not to be the component of meat responsible for the off-odors and flavors occurring in irradiated meat. However, Morgan (1957) indicated that natural antioxidants of fats were destroyed upon irradiation and could result in the formation of off-flavors due to the production of oxidized carbonyl compounds. It has been pointed out, however, that acid-salt extractable carbonyls, of low molecular weights, do arise from proteins. The Quartermaster Food & Container Institute (1958) indicated that hydrogen sulfide, methyl mercaptan, isobutyl mercaptan, dimethyl sulfide and dimethyl disulfide were compounds detected in irradiated beef. It was further noted that upon irradiation creatinine did not give rise to the irradiated flavor of beef. Kirn et al. (1956) reported that raw, cooked, cured or salted beef exhibited an off-flavor which did not show any correlation to quantities of either free fatty acids or peroxides. However, the undesirable flavor was correlated with amounts of tyrosine present on the surface of the meat. Kirn and co-workers also noted that tyrosine is tasteless, therefore, the off-flavor must be due to other factors.

It has been observed by some investigators that temperature, storage, gaseous surroundings and preirradiation treatment of meat all produce certain effects upon the flavor of irradiated meat. Hannan (1956) reported that fat irradiated at low temperatures had a more preferred flavor than fat irradiated at room temperature. He stated that this signifies less splitting of the fat molecule as was likely true in the former case. On the other hand, Schultz et al. (1956) stated that no significant difference in the intensity of irradiation flavor occurred between meats irradiated while frozen or unfrozen. Cain et al. (1956) indicated that irradiation flavor was independent of temperature, but was dependent on the level of irradiation. This work indicated that less irradiation flavor developed when the total irradiation level was delivered as eight successive exposures, rather than the entire exposure at once. The intensity of gamma rays used in irradiating the ground beef and the length of time needed to achieve the designated dosage had no effect on the extent of the development of irradiated flavors. Schultz et al. (1956) indicated that irradiation dosage of 124,200 to 993,600 reps produced a linear relationship between irradiation dosage and the intensity of irradiation flavor in ground beef. Huber (1945) stated that the irradiation flavor of meat tended to disappear during storage. Kirn et al. (1956) also reported that irradiated meat had a tendency to improve flavor-wise upon storage under anaerobic conditions. Other investigations have shown an initial improvement in taste panel scores during storage of irradiated meat up to one month, after which a gradual decrease occurred. The decline was detectable at each succeeding test period until the elapse of approximately 12 months, when all samples again exhibited an increase in taste preference (Pearson et al., 1959a).

Meat canned in atmospheres of air, vacuum or nitrogen showed no significant difference in the intensity of off-flavors when irradiated, except in the case of frankfurters (Schultz et al., 1956). This is in agreement with Hannan (1956) who wrote that irradiated vacuum-packed beef improved in flavor through the disappearance of the irradiated off-flavors when stored at 98° F. for one week. To the contrary Pratt and Ecklund (1954) reported that beef irradiated at 2.0 megarep and stored at 42 and 98° F. for a period up to 5 months showed no changes in the off-flavor. Schultz et al. (1956) reported that combining heat treatment (partially or completely cooked meat) or dehydration with irradiation did not reduce the production of the irradiation flavor and may actually intensify it. In the work of Kirn et al. (1956), however, it was concluded that heat processing prior to irradiation yielded a more desirable flavored product upon long storage.

It has been postulated by some investigators that the addition of compounds in vitro and in vivo may result in masking or reducing the amount of irradiation needed to yield the same degree of preservation. Pearson et al. (1958) found that the presence or absence of an oxygen scavenger, such as glucose oxidase, did not significantly influence acceptability, however, there was exhibited a trend for higher mean scores upon the addition of it. Activated carbons have been effectively utilized in reducing the irradiation flavor of beef (Tausig and Drake, 1959).

Anonymous (1958) reported that antibiotics combined with irradiation allowed the use of lower levels of irradiation, thus reducing the production of off-flavors. The storage life of meat containing Biostat, an antibiotic preparation developed by Charles Pfizer and Company, was extended 85 per cent longer than untreated meats. Irradiation alone produced an average increase of 150 per cent, while the Biostat-irradiation combined treatment caused an increase of 230 per cent. The Quartermaster Food & Container Institute (1958) also indicated that by combining irradiation and antibiotics to preserve meats, the amount of irradiation required can be reduced, thus protecting the flavor. Pearson et al. (1958) reported that the addition of salt to irradiated meat subjected to taste panel evaluation was not necessary because it was unable to mask the irradiated flavor or have any noticeable influence on the flavor of unirradiated meat. Schultz et al. (1956) stated that results obtained from their work suggested that the irradiation flavor is one which persons may become accustomed to if tasted over a period of time.

Texture and Juices

It is evident from observations and taste panel evaluations that undesirable changes have occurred in the texture and juices of irradiated meats. It is most common to identify with irradiated meats a mushy sensation upon chewing. Batzer et al. (1959) stated that aging at high temperatures produced meat of rubbery texture when irradiated at 8 megarads, however, at lower irradiation levels of 2 and 4 megarads there occurred the production of a soft texture. It was noted that these unnatural textures were undesirable upon evaluation. Hannan (1956) indicated that in his work no detectable changes in meat texture was observed when 2 megareps were used as the irradiation dosage. Pearson et al. (1958) reported that loss of desirable texture appeared to be related to storage time and temperature. It was noted that when storage time and temperature were increased a loss of desirable texture occurred in irradiated meat. The work of Perron and Wright (1950) indicated that high level irradiation of collagen brought about extensive structural changes which might explain the subsequent loss of desirable texture and moisture characteristics of meat. Kirn et al. (1956) on the other hand, reported that the texture of both precooked and raw irradiated meat were usually desirable.

In association with changes in texture are alterations in the natural juice retention of irradiated meat. The literature indicated that this is especially true of ground beef, in which considerable red meat juice is released. Morgan (1957) reported that proteins generally have their viscosity affected by irradiation. Morgan found in agreement with Perron and Wright (1950) that protein in a liquid medium tends to lose its specific structure, shrink and produce gels when irradiated. When in a dry medium protein is degraded with a loss of viscosity and an increased solubility. These investigators indicated that these protein changes may be the factors involved in the "drip" problem observed with irradiated meats.

Microbiology

Meat subjected to irradiation contains far fewer microorganisms than non-irradiated meat. The extent of microbial destruction depends upon many factors. The level of irradiation, susceptibility of the microorganisms to irradiation, their stage of development, numbers present in the meat and a host of other microbial environmental conditions are of grave importance. It appears that radiation interfers with proper and total cell division.

Fresh beef usually contains gram positive bacteria as its main flora, however, upon storage Pseudomonas becomes the predominating microflora. Work at the Quartermaster Food & Container Institute (1957) indicated that pasteurizing doses of 15,000 rads were sufficient to inflict a 99 per cent kill upon Pseudomonas organisms and the resistant flora were primarily gram positive Microbacterium. Wolin et al. (1957) reported that fresh beef stored at 36° F. in a humid atmosphere spoiled rapidly due to the growth of Pseudomonas geniculata and related species. It was indicated that these microorganisms are essentically the most sensitive to gamma radiation. With large populations in culture medium and juices the dosage required for a 99 per cent kill was 23,000 and 34,000 rads, respectively. With this treatment spoilage was eventually caused by Microbacterium thermosphactum which was resistant to these levels of irradiation. Kempe et al. (1957) observed no increased lethality from Clostridium botulinum 213 B spores when heated for 8 to 25 minutes at 210° F. before irradiation, however, when spores were irradiated followed by heating at 210° F. the number of spores surviving this sequence of combined treatment were markedly reduced.

Salmonella, Streptococci and Staphylococci, food poisoning causative bacteria, are very susceptible to the effects of irradiation (Quartermaster Food & Container Institute, 1957). Clostridium botulinum, however, aside from being one of the most dangerous microorganisms from a public health standpoint, is also one of the most irradiation resistant spore forming bacteria known. Morgan (1957) indicated that the sterilization dose of irradiation necessary to achieve a 99 per cent kill of Cl. botulinum ranged between 3 and 5 megareps.

The use of antibiotics injected in vitro has reduced the level of irradiation necessary to maintain the same degree of preservation as obtained from higher irradiation levels. Cain et al. (1958) injected hogs with oxytetracycline prior to slaughter and obtained meat of lower initial microbial count thus reducing the level of irradiation necessary for preservation. Drake et al. (1958) reported similar results using chlorotetracycline.

Enzymes

Much of the inability of raw meat to maintain its edibility is due to the activity of naturally occurring enzymes. Many spoilage microorganisms can be killed by moderate levels of irradiation, however, the dosage required to inactivate enzyme systems is much larger. Doty and Wachter (1955) reported that irradiation with cobalt-60 at dosages of 0.5 megareps produced little reduction of proteinase activity in beef muscle, however, dosages of 1.6 megareps reduced the apparent proteinase activity approximately 50 per cent. It was indicated that this level of activity would probably be sufficient to catalyze proteolytic changes in raw meat. Sheffner et al. (1957) stated that beef irradiated at 2 megareps exhibited only minor changes in the concentration or enzymatic availability of beef irradiated up to dosages of 3 megareps. The Quartermaster Food & Container Institute (1957) reported that beef steak irradiated at 5 megareps caused an approximate 50 per cent decrease in proteolytic enzyme activity.

Since cooked meat has its enzyme systems destroyed, due to the denaturation of their proteins, several investigations were initiated to study the combined use of heat and irradiation as a means of enzyme inactivation. The Quartermaster Food & Container Institute (1958) pointed out that temperatures of 140 to 160° F. will be required to bring about enzyme destruction. Proctor (1957) reported similar findings noting the thermal inactivation time of proteolytic enzymes in beef slices subjected to 3 megarads of irradiation to be between 6 and 8 minutes at 160° F. or 2 to 4 minutes at 170° F.

Wholesomeness and Toxicity

In any type of meat preservation the question, "Is this meat wholesome, of suitable nutritional value, of adequate palatability and completely void of toxic and carcinogenic compounds?," is asked by the potential consumers. Poling et al. (1955) reported that irradiated raw ground beef when fed to rats over a period of two years exhibited no major differences between the control and the experimental animals. Occasionally there was noted, however, a small decrease of statistical significance in growth, food efficiency, reproduction, adult body size and survival of the rats fed the irradiated meat. These items were considered to be due to the slight decrease in nutritional quality, similar to that which occurs during heat sterilization, and not that of toxic effects. These results were in agreement with those of Becker et al. (1956) who also indicated that certain essential nutrients are destroyed to varying degrees when subjected to sterilizing doses of irradiation. Becker and co-workers also reported that during the first generation all female animals were fertile, but succeeding generations exhibited a decrease in fertility of approximately 50 per cent. A decrease of radiation-sensitive vitamin E was given as an explanation by the investigators. Morgan (1957) reported that conscientious objectors, fed irradiated foods composing 35, 65, 85 and 100 per cent of their total diet, were used to evaluate the toxicity of various irradiated foods. The results of this test revealed no adverse effects from eating irradiated foods at any of the various levels. Morgan further stated that vitamin destruction was caused by irradiation and that the retention of these vitamins was similar to that which resulted from heat processing.

Animal Maturity

The question of what effects animal maturity has upon the acceptability of irradiated beef has been asked on numerous occasions. However, little investigation has been directed along these lines. It has been postulated that beef of varying levels of maturity might produce differences in acceptability upon irradiation. It is common knowledge that meat from younger animals contains a higher proportion of moisture than that of more mature animals. There may exist, between different levels of animal maturity, other chemical components which might alter the adverse organoleptic effects of irradiation.

Erdman and Watts (1957) and Pearson et al. (1958) investigated the effects of irradiation upon pork, beef and veal. In both experiments irradiated pork was preferred over either beef or veal, however, no indication was given concerning the latter two as to which one of them was the more preferred. It has been reported that beef was usually less acceptable than pork, while the desirability of veal was moderate (Quartermaster Food & Container Institute, 1958). Pearson et al. (1959b) reported that irradiated precooked pork was less adversely affected than veal and especially beef. From this investigation it was concluded that irradiated precooked veal was preferred by the taste panel to that of beef. Chemical differences observed between veal and beef were those of hydrogen sulfide, methyl mercaptans and acid-salt soluble carbonyls. Pearson and co-workers found that veal and beef differed significantly in their content of these three compounds after irradiation. In beef the chemical components i.e., hydrogen sulfide, methyl mercaptans and carbonyls, and taste panel scores were significantly negatively correlated. Veal also showed hydrogen sulfide and carbonyls significantly correlated with taste panel scores while the correlation between methyl mercaptan and taste panel scores was insignificant. It was further mentioned that carbonyls appears to be the one chemical component most promising as an indication of taste panel scores, although, they probably were not directly responsible for the off-odor and flavor of irradiated meats.

Fat Content

Fat is a natural occurring constituent of meat. As the animal becomes more mature and growth is satisfied energy in excess of body maintenance is expressed as fat deposition. Because fat is an inseparable component of meat the effects of radiation regarding it must also be understood. This phase of investigation has received more attention than the aspect of animal maturity.

Batzer and Doty (1955) reported that the water-soluble proteins of lean were largely responsible for the development of off-odors in irradiated meat and not the fat. Sribney et al. (1955) also reported that fat appeared not to be implicated in the flavor or odor of irradiated meat. Their basis for such a conclusion stemmed from the fact that irradiated beef containing considerable marbling produced less offensive flavor and odors. It was also noticed that beef of high fat content, when subjected to the same level of irradiation as low fat beef, released less hydrogen sulfide (Marback and Doty, 1956). Morgan

(1957) indicated that although both fat and protein were degraded by irradiation, protein was probably the larger cause of off-odors and flavors. Batzer et al. (1957) stated that products of fat breakdown produced by irradiation are not directly related to off-odors and flavors. It was also pointed out that meat of higher fat content had lower carbonyl values than did leaner meats, indicating that fat content contributed very little to the production of carbonyl compounds during irradiation. Other investigations have pointed out that correlation coefficients between taste panel scores and the per cent fat are negative, but are not of statistical significance (Pearson et al., 1959a).

EXPERIMENTAL PROCEDURE

I. Materials

The ground meat utilized throughout this investigation was obtained from the chucks of Hereford cattle of similar breeding. The animals were divided into three lots with each lot being slaughtered at different stages of maturity. Lots I, II and III were composed of 6, 12 and 24 month old animals, respectively, at the time of their slaughter.

Polymylar bags, sealed under vacuum, were used as the packaging material for the ground meat. Enameled sanitary tin cans, sizes No. 10 and 303, were used to provide mechanical protection to the ground beef filled bags.

Gamma rays derived from spent fuel elements were used to irradiate the canned ground beef.

A trained taste panel team was used as a means of evaluating the experimental product.

II. Methods

A. Experimental Animals

Hereford cattle of Line-4 breeding were selected from the stock at Fort Reno Experiment Station. Those animals selected for use were divided into three lots. Each lot represented a different level of animal maturity at the time of their slaughter. Lots I, II and III consisted of 6, 12 and 24 month old animals, respectively. In addition each level of animal maturity was further subdivided into two different planes of nutrition. One half of the animals in each maturity group were fed on a high plane of nutrition to yield carcasses possessing a high degree of fat deposition. The remaining one half were fed a lower plane of nutrition to insure carcasses of low amounts of fat deposition. Both steers and heifers of compressed and non-compressed type were balanced within each lot. However, since ground beef was the source of product used in this experiment no attempt was made to maintain animal, sex or type identity.

B. Preparation of Product

Each group of animals was slaughtered as they reached the stage of maturity set up for their respective lot. Animals within each lot were trucked from the Fort Reno Experiment Station to the experimental facilities of the Meat Laboratory at Stillwater 24 hours prior to slaughter. During this time the animals were allowed to shrink and alleviate, in part, the stress which resulted from the handling-transit operation. The slaughter procedure was conducted in the manner recommended for experimental cattle set forth by the Fourth Annual Reciprocal Meat Conference of 1951. The carcasses were chilled approximately 48 hours at 36° F. The right chuck was cut from each carcass, boned and de-fatted in such a manner as to yield meat of high and low fat content. Chemical analysis revealed the low fat content meat from the three maturity levels to contain approximately 8 per cent fat while the high fat content meat contained approximately 28 per cent fat. (Determinations made by staff members of Biochemistry Department.)

The two fat levels of meat were ground separately through the Interprise "56" meat chopper. The ground beef of each fat level was ground twice, first, using a coarse plate (1/2 inch) followed by a finer plate (1/8 inch). The meat was kept under refrigeration (30-36° F.) during the preparation procedure except for the short time needed for grinding.

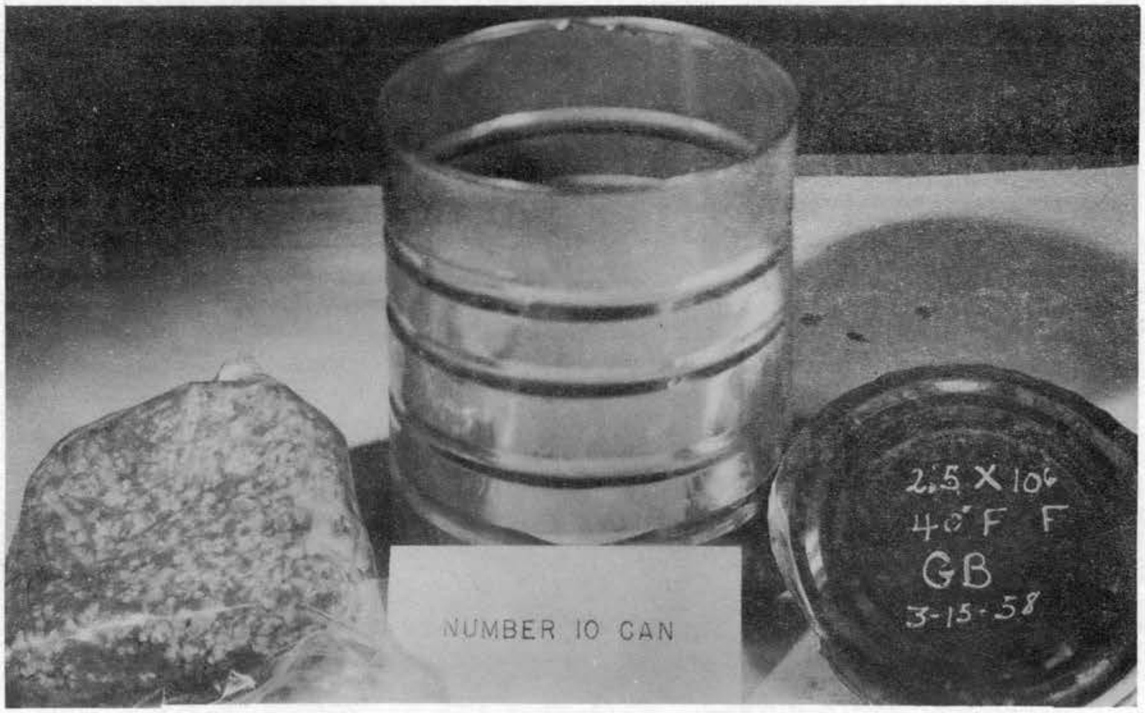
C. Preparation for Irradiation

In preparation for irradiation enameled sanitary tin can lids were labeled in the prescribed method set forth by the Quartermaster Food & Container Institute. Each can lid was labeled with one of four colored marking pencils depending upon the level of irradiation it was to receive. Colors of red, yellow, white, white and green were used to indicate 5.0, 2.5, 0.5, 0.1 and 0.0 megarad levels of irradiation, respectfully. The label on each can lid indicated: (1) the type of product, (2) storage temperature, (3) storage period, (4) irradiation level and (5) the date canned (Plate I,1).

Labeled can lids and cans were then autoclaved at 120° C. for 20 minutes (15 pounds pressure) to insure sterilization prior to canning. Cans and lids were removed from the autoclave after the sterilization process and preparation was made for canning.

The procedure used for canning the ground beef was that of one of two methods. The first, using the ground beef from the 12 month old animals, involved packaging the ground beef in polymylar bags. Each bag contained approximately 2 pounds of ground beef (Plate I,1). After filling each bag, a vacuum of 25 inches was drawn on the bag and sealed by the use of a Cryovac vacuum processing machine. Three vacuumed-sealed bags of ground beef were then placed in a No. 10 (603 x 700) sterilized can. The cans were then sealed by a portable canning machine. In this method a total of 40 No. 10 cans of ground beef were used in the experiment (Figure 1).

PLATE I



1. Cans of ground beef from 12 month old animals

2. Cans of ground beef from 6 and 24 month old animals

12 Month Old Animals

	Low Fat Content				High Fat Content				
	0° F.		40° F.		0° F.		40° F.		
	Weeks		Weeks		Weeks		Weeks		
Dose Level (Rads)	0 2 4	6 8 10	2 4	6 8 10	0 2 4	6 8 10	2 4	6 8 10	
5×10^6	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	= 8 cans
2.5×10^6	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	= 8 cans
0.5×10^6	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	= 8 cans
0.1×10^6	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	= 8 cans
Non-Irrad.	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	= 8 cans
	10 cans		10 cans		10 cans		10 cans		
	20 cans				20 cans				
	40 cans								

Figure 1. Allocation of canned ground beef for 12 month old animals

A second method, as was used with the 6 and 24 month old animals, consisted of placing the ground beef directly into a No. 303 (303 x 406) sterilized can without using a polymylar bag (Plate I,2). However, one or two small, handmade polymylar bags containing 50 grams of ground beef was added to each can depending upon the storage temperature to which the can would be subjected to during its storage period. Cans stored at 0° F. contained only one bag of meat which was used for chemical analysis. The cans stored at 40° F., however, contained two bags of meat, one of which was used for chemical analysis and the second for a bacteriological assay. The latter 50 gram bag was added to the can for use in detecting any microbial toxins which might have developed during this elevated storage period. The bacteriological assay was preformed by staff members of the Bacteriology Department. The Mouse Assay Procedure as prescribed by Quartermaster Food & Container Institute was used entirely. The cans in this method were then sealed as previously stated. The cans were not sealed under vacuum as no facilities were available for this process. A total of 220 No. 303 cans were used in this phase of the experiment (Figure 2). Regardless of the method used all sealed cans were placed under 35° F. refrigeration over night to allow the oxygen to be utilized by microorganisms and enzymes present in the meat prior to freezing. The following day the sealed cans were placed under 0° F. refrigeration to await shipment to the site of irradiation.

In agreement made with the Quartermaster Food & Container Institute, it was specified that all products to be irradiated would be handled by the Phillips Petroleum Company located near Idaho Falls, Idaho. The irradiation produced at this site was of the gamma ray type arising from

6 and 24 Month Old Animals

	Low Fat Content											High Fat Content											
	0° F.						40° F.					0° F.						40° F.					
	Weeks						Weeks					Weeks						Weeks					
Dose Level (Rads)	0	2	4	6	8	10	2	4	6	8	10	0	2	4	6	8	10	2	4	6	8	10	
5×10^6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	= 44 cans
2.5×10^6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	= 44 cans
0.5×10^6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	= 44 cans
0.1×10^6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	= 44 cans
Non-Irrad.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	= 44 cans
	60 cans						50 cans					60 cans						50 cans					
	110 cans											110 cans											
	220 cans																						

Figure 2. Allocation of canned ground beef for 6 and 24 month old animals

spent Materials Testing Reactor Fuel Elements.

In preparation for shipment, via air freight to the atomic reactor, the frozen cans of ground beef were placed into frozen food packers containing 50 pounds of dry ice per packer. The addition of dry ice was designed to maintain the frozen state of the ground beef during transit. Due to the relatively short effectiveness of dry ice the packers were opened and checked for adequate dry ice content systematically along the air route. Being a highly perishable product, the ground beef was irradiated in a frozen state upon reaching the atomic reactor. After being irradiated the ground beef was then returned by air freight in the same manner that it was sent. Due to the shipping expense involved only the ground beef to be irradiated was shipped to the irradiation center. The control samples remained frozen at this station during the irradiation of the designated cans.

D. Storage Procedure

Upon the return of the irradiated ground beef to the Experiment Station Laboratory, both the irradiated and non-irradiated samples were assigned to their respective storage treatments. The storage treatment was divided into two parts with storage temperature being the first and storage period the second. Throughout the storage period one half of the product was stored at a refrigerated temperature of 0° F. while the remaining one half was stored at 40° F. Cans representing each level of animal maturity, fat content, irradiation level and storage temperature were assigned to storage periods of 0, 2, 4, 6, 8 and 10 weeks consecutively (Figure 2). Upon completion of each two weeks storage interval cans refrigerated at 40° F. were opened for bacteriological analysis.

Upon completion of the analysis all negative reacting samples were tasted by the taste panel.

E. Bacteriological Procedure

Presuming that little or no microbial decomposition or toxin production occurred at 0° F., only the ground beef stored at 40° F. was analyzed for possible microbial adulteration. At the end of each storage period designated cans were removed from storage and opened. A 50 gram sample of ground meat was asceptically removed from each quantity of meat to be tasted. The method of removing the ground beef for analysis varied depending upon the method of canning. Ground beef, as previously mentioned, from the 12 month old animals was sealed in two pound bags, three of which were placed in a No. 10 can. One bag was sufficient to hold the quantity of meat needed for both the bacteriological analysis and taste panel evaluation for one storage period. A No. 10 can, therefore, contained enough meat for three storage periods. In taking samples for bacteriological analysis the end of each bag was opened with a sterilized knife. Fifty grams of meat were then removed from each sample and placed in separate petri dishes. The lid of each petri dish was labeled for identification and delivered to the Bacteriology Department for analysis. After removing the 50 gram meat samples the bags were then resealed and refrigerated at 0° F. until completion of the bacteriological analysis. The time allocated for such an analysis was approximately one week, at the end of which the frozen bags were reopened and the meat prepared for taste panel evaluation providing the analysis proved negative.

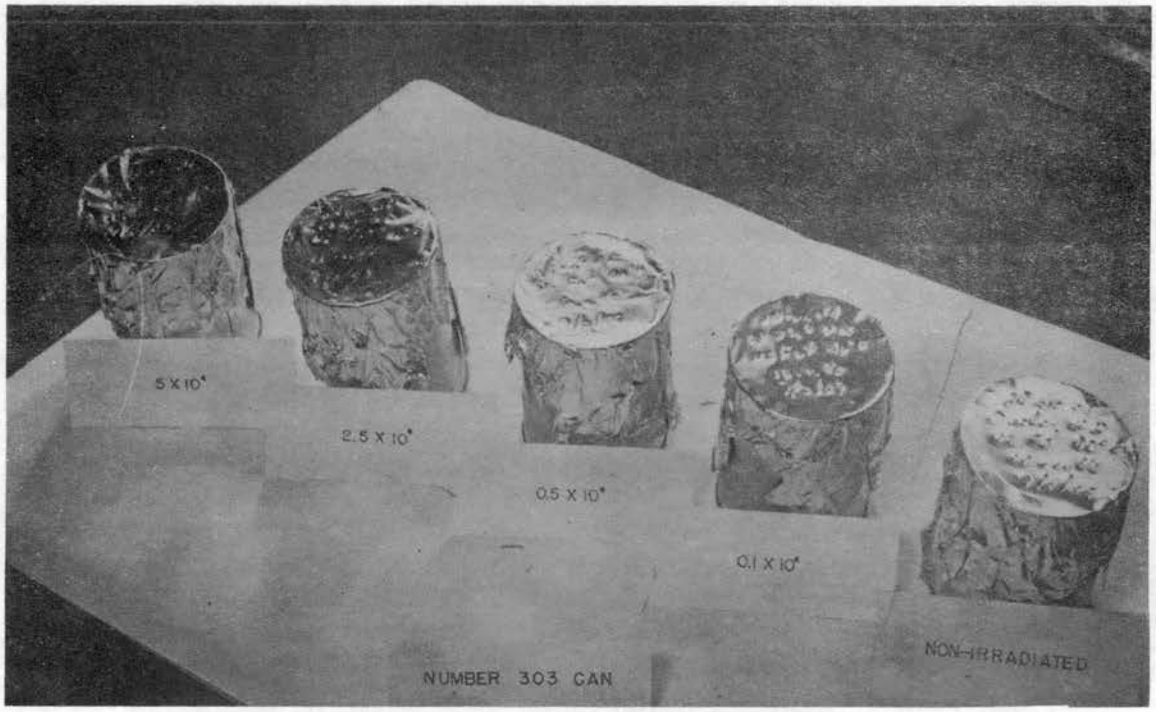
The second method of removing 50 gram samples of ground beef for analysis was designed to facilitate this operation. During the canning of ground beef from the 6 and 24 month old animals one or two small polymylar bags, filled with 50 grams of meat, were added to each No. 303 can. Removing samples of meat for bacteriological analysis in this instance meant simply opening the cans to be tasted and removing a 50 gram bag of meat from each can. Each sample upon removal was encircled by a piece of tape bearing a number which identified it as to its maturity, fat content, level of irradiation, storage temperature and storage period. The samples were then delivered to the Bacteriology Department for analysis. After removing the samples the cans were covered with aluminum foil and placed under 0° F. refrigeration (Plate II,1). Upon completion of the analysis all negative samples were subjected to taste panel evaluation. It was conceded that this technique would save time in removing samples while reducing the possibility of contamination which might occur during its removal as mentioned in the previous method.

The procedure followed by the Bacteriology Department in making their analysis was the Mouse Assay Procedure prepared by the Nutrition Branch of the Quartermaster Food & Container Institute. This test was primarily designed to detect *Clostridium botulinum* toxins which might be present in foods being evaluated by the taste panel. The procedure was as follows:

(1) Preparation of the sample

The sample was suspended in 10 volumes of sterile normal saline and allowed to stand at room temperature for one hour. The material was then centrifuged at high speeds for one hour. The supernatant was then drawn off and placed in a refrigerated section of the laboratory. The container was labeled, For Contaminated Foods Only, Caution, in red print.

PLATE II



1. Cans reclosed after removal of bacteriological sample

2. Experimental animals for the Mouse Assay

The supernatant was saved until the termination of the analysis.

(2) Administration of supernatant

One-half ml. of the supernatant was drawn into a sterile syringe fitted with a 22 gauge needle. Using a white mouse, the site of injection was disinfected by the application of 2 per cent iodine in alcohol. The entire thickness of the abdominal parietos was pinched up into a triangular fold with the left hand. The peritoneal surfaces were then slipped over each other to ascertain that no coils of intestines were included. The syringe was grasped with the right hand and the needle was inserted into the fold near its base. The fold was then released and the supernatant was injected into the mouse. To the site of injection was applied a coating of collodion. The mouse was then placed in a clean cage clearly designated with a code number of the injected material. A second mouse was treated exactly in the same manner and placed in the same cage to serve as a check. Food and water were fed ad libitum (Plate II,2).

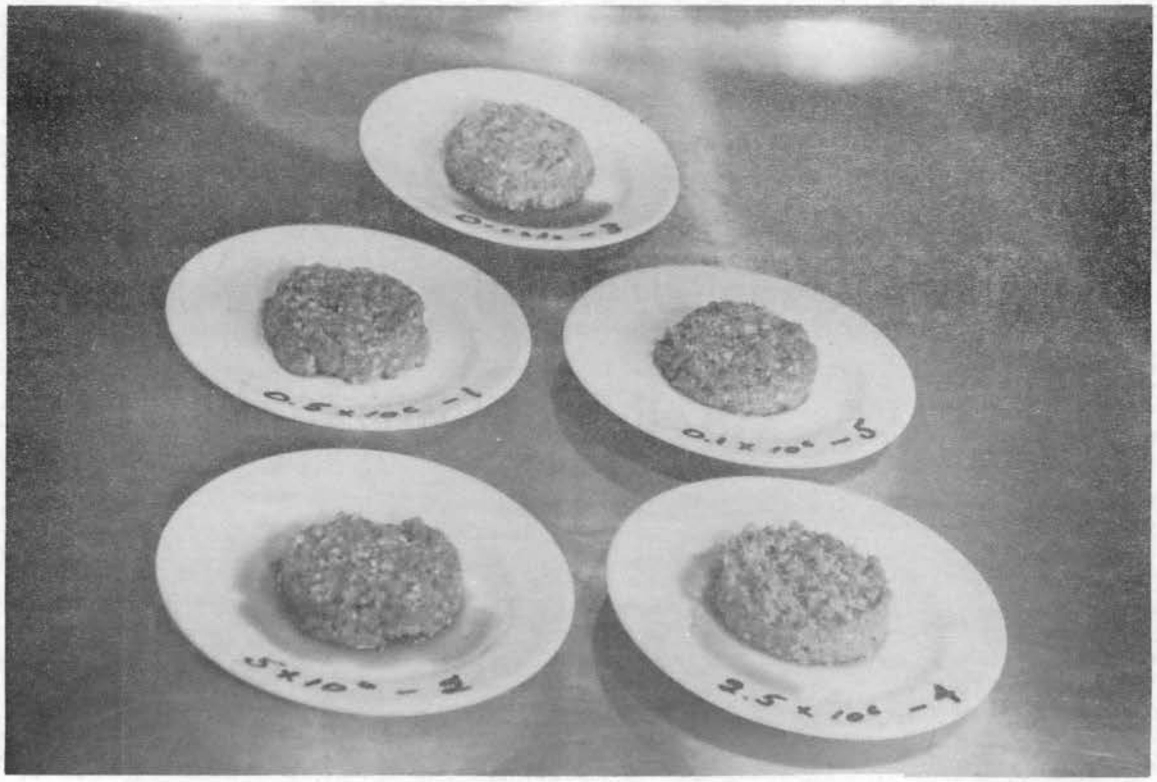
(3) Observation of mice

The symptomology observed for was, extreme weakness, flabby abdominal muscles, respiration paralysis, increased secretions of mucus from the nose and mouth, diarrhea and death. Gloves were worn to handle animals during their observation after which such time they were placed in a covered container for sterilization. Systematic observations were conducted at 4, 24 and 48 hours, recording at each time either negative or positive findings. Each observation was initialed and dated to provide maximum protection. In the event of illness or death of the experimental animals the person in charge was notified. If death occurred the animal, its food and excreta were removed and burned. The cage, feeder and waterer were washed in a 1 per cent cresol solution and then sterilized. A follow-up assay was made on suspensions causing or suspected of causing the death of the mouse. Two additional mice were injected with the saved portion of the supernatant to recheck the cause of death. A quantity of the supernatant was then boiled in a water bath for one hour and two mice were injected with this preparation. The observation of symptoms was the same as previously mentioned. If the saved portion of the supernatant again caused death the cause was attributed to Cl. botulinum. If, however, death resulted from the boiled supernatant preparation the death was attributed to the presence of causative agents other than Cl. botulinum. Mice previously used in this assay were not reused.

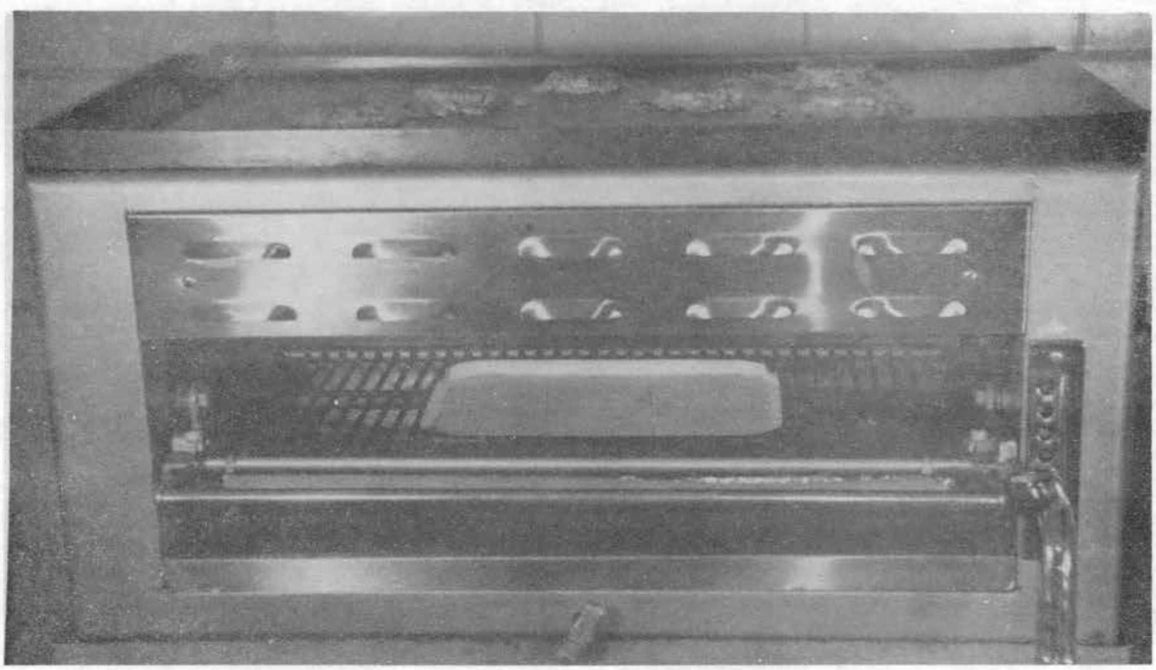
F. Cooking and Tasting Procedure

At the end of each storage period preparations for cooking the samples stored at 0 and 40° F. were made, providing negative bacteriological analyses were obtained from samples stored at 40° F. Bags or cans, depending upon the canning method used, were removed from the freezer and samples for tasting were removed from each. A total of five samples were evaluated by the taste panel during each session. The quantity of meat to be tasted was divided into two samples. One of which was tasted as soon as it could be prepared while the remaining half samples were returned to the freezer to await evaluation 24 hours later. The frozen ground beef was allowed to thaw at room temperature. The meat was then made into patties of approximately 3 1/2 to 4 inches in diameter and 1 inch thick. The patties were given code numbers at random from one to five to maintain their identity during cooking while remaining anonymous to the taste panel members (Plate III,1). The

PLATE III



1. Meat coding prior to cooking



2. Grill cooking of ground beef patties

patties were cooked on an open grill which has been preheated at 350° F. for one hour (Plate III, 2). Samples were cooked approximately 10 to 12 minutes or until the internal portions of the patties had become brown. The patties were then removed from the grill, cut into individual pieces approximately 3/4 of an inch square and served to an awaiting taste panel. It was the practice at the beginning of the experiment to serve the coded samples in sequence, 1 through 5. This procedure was altered, however, in view of the fact that tasting fatigue could occur thus subjecting the last sample served to a biased or harsh evaluation. Therefore, each score sheet (Figure 3) was provided with a random array of numbers from 1 to 5. The samples were then served in this manner to the panel. The score sheets used for flavor preference was based on a 9 point hedonic scale. No salt was added to the patties at any time, realizing that this might in part conceal the irradiation or other adverse flavors of the meat and that individual seasoning preference varies considerably.

Each sample of ground beef was systematically evaluated by each member of the taste panel (Plate IV). The first step in this sequence consisted of placing into the mouth the sample of ground beef to be evaluated. It was then chewed until a suitable answer was reached concerning its desirability or preference. After being evaluated and noted on the flavor preference score sheet the chewed sample was removed from the mouth into a paper cup. The second step consisted of the members placing into their mouths a small piece of bread which was chewed and also removed from the mouth. Each member then rinsed his mouth with tap water from a second paper cup and it too was removed from the mouth, thus completing the third step. At this time the members

PREFERENCE

Name ____________________ Date ____________

CODE____	CODE____	CODE____	CODE____	
___Like Extremely	___Like Extremely	___Like Extremely	___Like Extremely	9
___Like Very Much	___Like Very Much	___Like Very Much	___Like Very Much	8
___Like Moderately	___Like Moderately	___Like Moderately	___Like Moderately	7
___Like Slightly	___Like Slightly	___Like Slightly	___Like Slightly	6
___Neither Like Nor Dislike	___Neither Like Nor Dislike	___Neither Like Nor Dislike	___Neither Like Nor Dislike	5
___Dislike Slightly	___Dislike Slightly	___Dislike Slightly	___Dislike Slightly	4
___Dislike Moderately	___Dislike Moderately	___Dislike Moderately	___Dislike Moderately	3
___Dislike Very Much	___Dislike Very Much	___Dislike Very Much	___Dislike Very Much	2
___Dislike Extremely	___Dislike Extremely	___Dislike Extremely	___Dislike Extremely	1
COMMENTS:	COMMENTS:	COMMENTS:	COMMENTS:	

Figure 3. Taste panel score sheet

were served their second sample and the process was then repeated. This procedure was continued until all five samples of irradiated ground beef were evaluated by the taste panel.

PLATE IV

Taste panel in session

RESULTS AND DISCUSSION

I. Animal Maturity

The effect of animal maturity upon taste panel acceptability of irradiated ground beef was investigated as a possible means of eliminating the adverse flavor and odor affects of irradiation. After being irradiated the ground beef from the 6, 12 and 24 month old animals was evaluated by the taste panel. After each setting of the panel, scores were tabulated from the nine point hedonic scale score cards. Upon completion of the storage period these data were processed and analyzed using the IBM "650" computer.

Taste panel means of ground beef from the 6 month old animals were compiled upon completion of the storage period and are presented in Tables A and B (Appendix). The analysis of variance computed from these data is shown in Table I. Ground beef from the 6 month old animals appeared to be influenced by the storage period. An analysis of the data indicated the storage period to be significant at the 1 per cent level. Taste panel means were variable throughout the 10 week storage period as shown in Table II,a. A study of the data in this table indicated a decline in taste panel acceptability as the storage period progressed, however, an increase in preference between 8 and 10 weeks of storage was observed. These phenomena are also schematically illustrated in Figure 4.

Storage temperature also was shown to affect the acceptability of irradiated ground beef from the 6 month old animals as pointed out in

TABLE I

ANALYSIS OF VARIANCE - ANALYTICAL TASTE PANEL SCORES OF GROUND BEEF FROM ANIMALS 6 MONTH OLD AT TIME OF SLAUGHTER

Source	d/f	SS	MS	F
Total	119	376.5816		
Fat Content	1	.2042	.204200	1.769
Storage Time	5	13.4759	2.695180	23.351**
Fat Content x Storage Time	5	2.4195	.483900	4.192**
Storage Temperature	1	90.7758	90.775800	786.481**
Storage Temp. x Storage Time	5	27.5036	5.500720	47.658**
Fat Content x Storage Temp.	1	4.0738	4.073800	35.295**
Fat x Time x Temperature	5	2.3593	.471860	4.088*
Irradiation Dose	4	32.9672	8.241800	71.407**
Storage Time x Irrad. Dose	20	39.4107	1.970535	17.073**
Storage Temp. x Irrad. Dose	4	119.8153	29.953825	259.520**
Time x Temp. x Dose	20	29.4667	1.473335	12.765**
Fat Content x Irrad. Dose	4	6.5872	1.646800	14.268**
Fat x Time x Dose	20	4.7729	.238645	2.068
Fat x Temp. x Dose	4	.4411	.110275	0.955
Fat x Time x Temp. x Dose	20	2.3084	.115420	

* $P \leqslant 0.05$

** $P \leqslant 0.01$

TABLE II

FLAVOR MEAN SCORES OF STORAGE TIME, STORAGE TEMPERATURE AND IRRADIATION LEVEL FOR THE RESPECTIVE MATURITY LEVELS[1]

a
Storage Period (Weeks)

Maturity	0	2	4	6	8	10	Mean
6 Mo. Old	5.05	4.41	4.96	4.19	3.97	4.21	4.47
12 Mo. Old	5.53	5.05	4.78	4.58	4.30	4.37	4.77
24 Mo. Old	5.60	5.20	4.27	4.29	4.33	4.33	4.67
Mean	5.39	4.89	4.67	4.35	4.20	4.30	4.63

b
Storage Temperature (°F.)

Maturity	0	40	Mean
6 Mo. Old	5.24	3.69	4.47
12 Mo. Old	5.64	3.91	4.78
24 Mo. Old	5.38	3.97	4.68
Mean	5.42	3.86	4.64

c
Levels of Radiation (Megarads)

Maturity	5	2.5	0.5	0.1	0.0	Mean
6 Mo. Old	3.84	4.57	5.29	3.98	4.13	4.36
12 Mo. Old	4.49	4.81	5.60	4.52	4.37	4.76
24 Mo. Old	4.21	4.55	5.45	4.41	4.48	4.62
Mean	4.18	4.64	5.45	4.30	4.33	4.58

1 Nine point hedonic scale with a value of 9.0 being "like extremely."

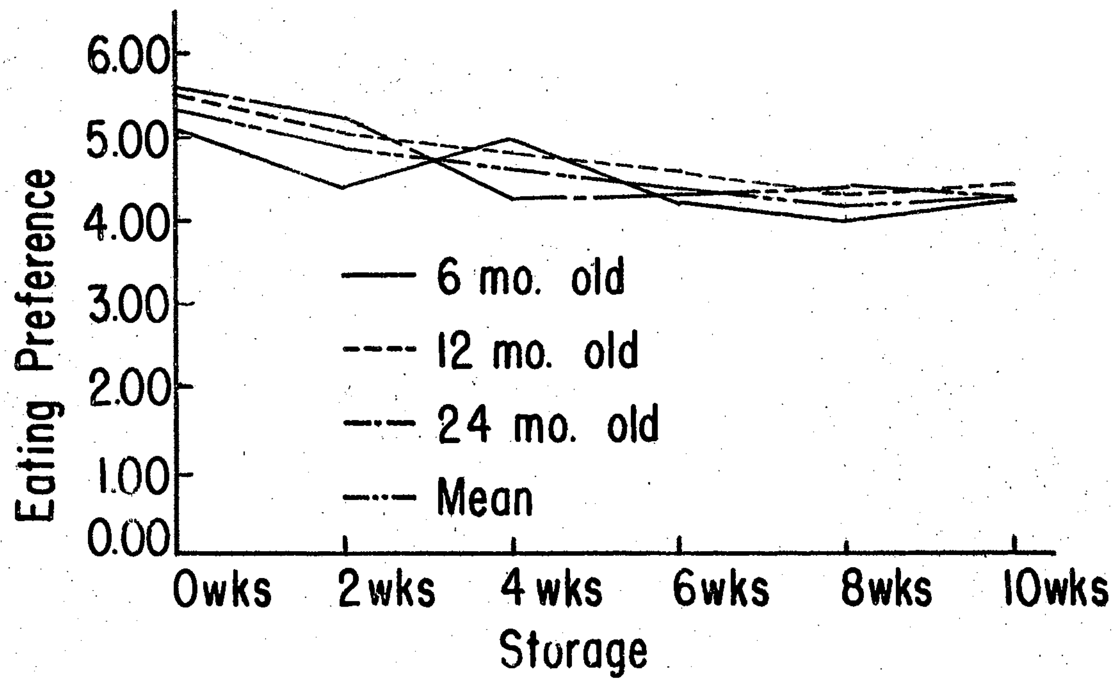


Figure 4. Taste panel means of irradiated ground beef from animals of different maturity as influenced by storage period.

Table I. The analysis of variance revealed the variable to be highly significant. The means for storage temperature were calculated and are presented in Table II,b to readily show where the significant difference was. The means from this table revealed 0° F. to be the more preferred storage temperature over that of 40° F. Although ground beef stored at 0° F. was preferred to that stored at 40° F. it was still rated as "neither like nor dislike" on the hedonic scale. Figure 5 illustrates the effect of storage temperature.

The irradiation level to which the ground beef from the 6 month old animals were exposed to was highly significant (Table I). The 0.5 megarad level of irradiation was the least discriminated dosage as shown in Table II,c. However, the taste panel mean for the 0.5 megarad level of irradiation was slightly higher than "neither like nor dislike." A decrease in taste panel scores occurred with the 0.5, 2.5, 0.0, 0.1 and 5.0 megarad levels of irradiation, respectively. The 0.5 megarad dosage was capable of destroying spoilage microorganisms to the point that they caused no adverse effects upon the flavor while still not being of high irradiation level to cause objectionable irradiation odors and flavors. The effect of irradiation dosage is illustrated in Figure 6. Table III,c reveals the mean values of ground beef subjected to various levels of irradiation and then stored at 0 and 40° F. storage temperatures. It was noted that this interaction was highly significant as shown in Table I. The ground beef stored at 0° F. did not improve in preference with the use of radiation as a combined method of meat preservation. Ground beef stored at 40° F. was also more preferred when the 0.5 megarad level of irradiation was used. However, with the ground beef stored at this elevated

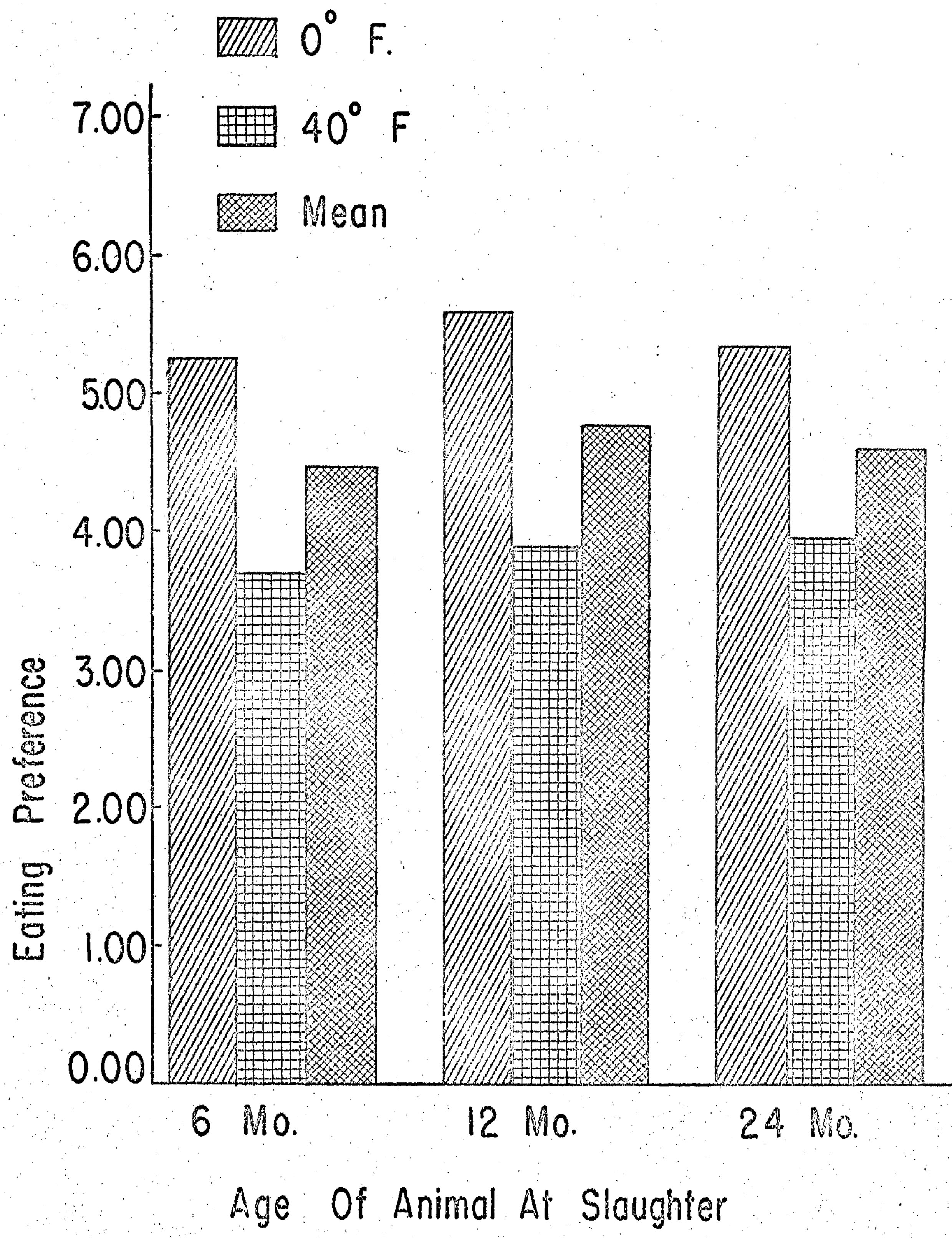


Figure 5. Taste panel means of irradiated ground beef from animals of different maturity as influenced by storage temperature.

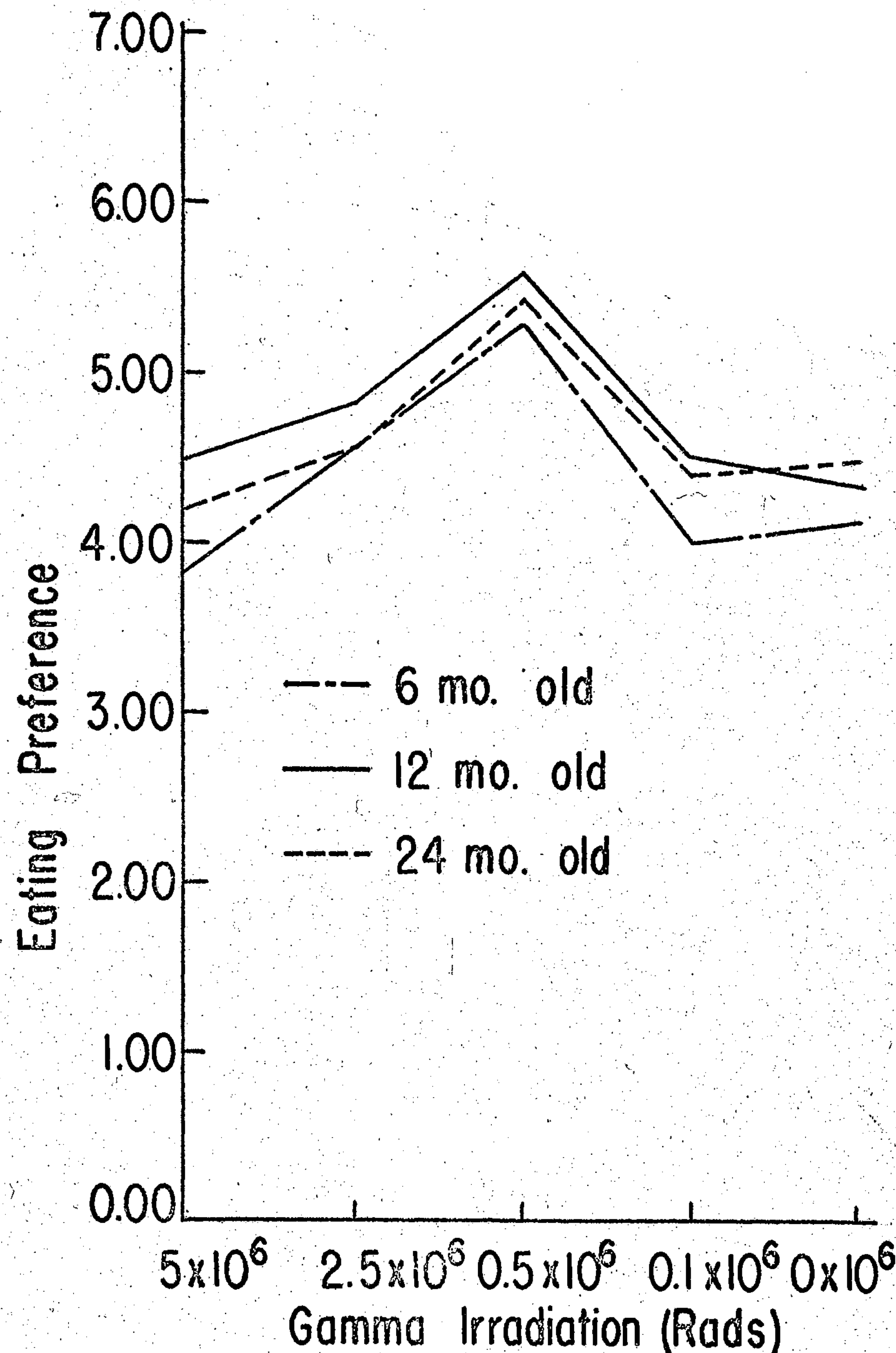


Figure 6. Taste panel means of irradiated ground beef from animals of different maturity as influenced by irradiation level.

TABLE III

FLAVOR MEAN SCORES OF GROUND BEEF FROM DIFFERENT ANIMAL MATURITY SUBJECTED TO VARYING LEVELS OF RADIATION AND TEMPERATURE

a

6 Month Old Animals

	Radiation (Megarads)					
Temperature	5	2.5	0.5	0.1	0.0	Mean
0° F.	3.76	4.51	5.63	5.99	6.29	5.24
40° F.	3.93	4.62	4.96	1.99	1.97	3.49
Mean	3.85	4.57	5.25	3.99	4.13	4.37

b

12 Month Old Animals

	Radiation (Megarads)					
Temperature	5	2.5	0.5	0.1	0.0	Mean
0° F.	4.50	4.70	5.88	6.42	6.61	5.62
40° F.	4.49	4.92	5.32	2.62	2.09	3.89
Mean	4.50	4.81	5.60	4.52	4.35	4.76

c

24 Month Old Animals

	Radiation (Megarads)					
Temperature	5	2.5	0.5	0.1	0.0	Mean
0° F.	3.84	4.34	5.42	6.14	6.61	5.27
40° F.	4.59	4.77	5.33	2.69	2.36	3.95
Mean	4.22	4.56	5.38	4.42	4.54	4.62

d

6, 12 and 24 Month Old Animals

	Radiation (Megarads)					
Temperature	5	2.5	0.5	0.1	0.0	Mean
0° F.	4.03	4.52	5.64	6.18	6.50	5.38
40° F.	4.34	4.77	5.20	2.43	2.14	3.78
Mean	4.19	4.65	5.42	4.31	4.32	4.58

temperature the higher levels of irradiation was necessary to maintain taste panel preference. Preference scores decreased when 0.5, 2.5, 5.0, 0.1 and 0.0 megarad levels of irradiation were used, respectively, when stored at 40° F. (Figure 7).

Similar results were shown to exist for the ground beef from the 12 month old animals as for the 6 month olds. Taste panel means for the irradiated ground beef from the 12 month old animals are shown in Tables C and D (Appendix). The analysis of variance for taste panel scores indicated storage period, storage temperature and irradiation level to be significant at the 1 per cent level as shown in Table IV. As reported for the 6 month old animals, the means of ground beef from the 12 month old animals exhibited a continuous decrease in taste panel scores throughout subsequent storage as shown in Table II,a. However, from 8 to 10 weeks of storage little change was noted in taste panel scores. These data are illustrated in Figure 4.

The data in Table II,b revealed that the 0° F. storage temperature was preferred to that of 40° F. Figure 5 also illustrated this point, but even at 0° F. storage the mean taste panel score did not reach "like slightly" on the hedonic scale, where as the product stored at 40° F. approached "dislike slightly."

The irradiation level was also highly significant for the 6 month old animals. Again the 0.5 megarad level of irradiation was the least discriminated against, followed by 2.5, 0.1, 5.0 and 0.0 megarad levels, respectively (Table II,c). This observation was obtained when both storage temperatures were pooled as illustrated in Figure 6. However, when the storage temperatures were considered separately this same sequence of preference for irradiation levels did not occur as shown in

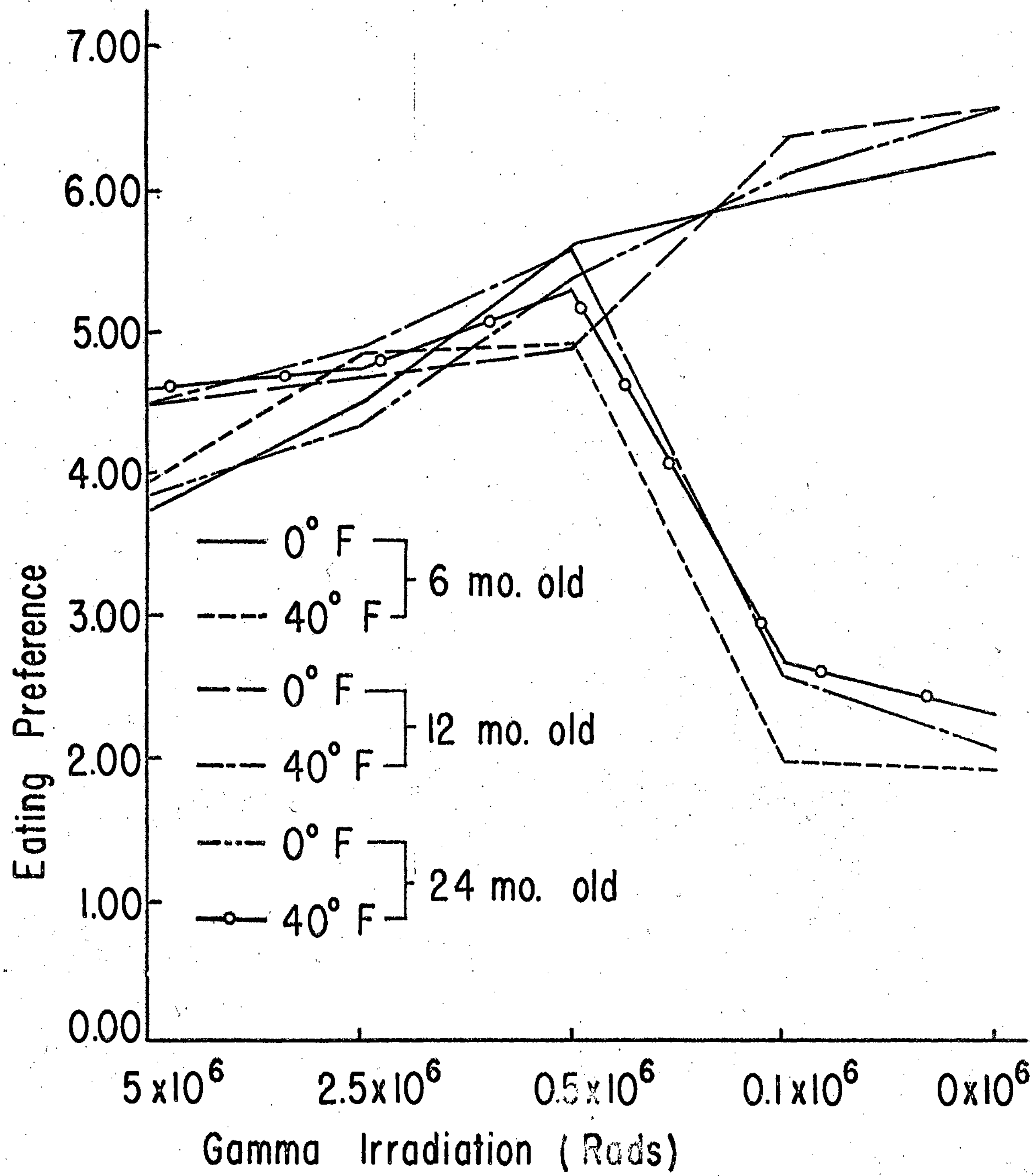


Figure 7. Taste panel means of irradiated ground beef from animals of different maturity as influenced by storage temperature and irradiation level.

TABLE IV

ANALYSIS OF VARIANCE - ANALYTICAL TASTE PANEL SCORES OF GROUND BEEF FROM ANIMALS 12 MONTH OLD AT TIME OF SLAUGHTER

Source	d/f	SS	MS	F
Total	119	382.4490		
Fat Content	1	7.1297	7.129700	12.910**
Storage Time	5	21.8072	4.361440	7.899**
Fat Content x Storage Time	5	11.0758	2.215160	4.010*
Storage Temperature	1	89.0446	89.044600	161.280**
Storage Temp. x Storage Time	5	17.5170	3.503400	6.350**
Fat Content x Storage Temp.	1	.6886	.688600	1.250
Fat x Time x Temperature	5	.5747	.114940	0.208
Irradiation Dose	4	23.7936	5.948400	10.770**
Storage Time x Irrad. Dose	20	25.8776	1.293880	2.340*
Storage Temp. x Irrad. Dose	4	119.4353	29.858825	54.080**
Time x Temp. x Dose	20	40.1655	2.008275	3.640**
Fat Content x Dose	4	.8873	.221825	0.402
Fat x Time x Dose	20	12.6755	.633775	1.150
Fat x Temp. x Dose	4	.7346	.183650	0.333
Fat x Time x Temp. x Dose	20	11.0420	.552100	

* $P < 0.05$
** $P < 0.01$

Table III,a. Figure 7 aids in illustrating this point.

Tables E and F (Appendix) contain the taste panel means for the 24 month old animals. The analysis of variance of these data is presented in Table V. The effects of storage period, storage temperature and irradiation level were all similar to that of the 6 and 12 month old animals in that these three variables were all significant at the 1 per cent level. Table II,a presents the storage period means for the 24 month old animals for the entire period of 10 weeks at 2 week intervals. These data revealed a rapid decline in preference up to 4 weeks of storage, after which time the preference remained relatively constant throughout the remaining 6 weeks of storage. It was noted, however, as shown in Figure 4 that taste preference has increased somewhat by the 10 week storage period as compared to 4 and 6 weeks of storage. It was interesting to note that this initial decrease in taste preference during storage occurred with all three levels of maturity while panel scores at 10 weeks storage had increased above that of the previous storage period.

The 0° F. storage temperature was the more preferred temperature of the two as pointed out in Table II,b and illustrated in Figure 5. The 0° F. storage temperature exhibited taste panel means slightly in excess to "neither like nor dislike" or 5.0 on the 9 point hedonic scale, while taste panel means of the 40° F. storage temperature were approximately 4.0 or "dislike slightly."

As was found to occur with the 6 and 12 month old animals, the 0.5 megarad level of irradiation was the least discriminated dosage as reported in Table II,c. This table also indicated the levels of irradiation arranged in order of decreasing preference to be 0.5, 2.5, 0.0, 0.1

TABLE V

ANALYSIS OF VARIANCE - ANALYTICAL TASTE PANEL SCORES OF GROUND BEEF FROM ANIMALS 24 MONTH OLD AT TIME OF SLAUGHTER

Source	d/f	SS	MS	F
Total	119	335.5384		
Fat Content	1	.7115	.711500	3.622
Storage Time	5	31.0024	6.200480	31.567**
Fat Content x Storage Time	5	3.4163	.683260	3.478*
Storage Temperature	1	54.8371	54.837100	279.176**
Storage Temp. x Storage Time	5	13.2874	2.657480	13.529**
Fat Content x Storage Temp.	1	.9901	.990100	5.041*
Fat x Time x Temperature	5	2.9040	.580800	2.957*
Irradiation Dose	4	22.1728	5.543200	28.220**
Storage Time x Irrad. Dose	20	30.4458	1.522290	7.750**
Storage Temp. x Irrad Dose	4	129.6728	32.418200	165.041**
Time x Temp. x Dose	20	33.6610	1.683050	8.568**
Fat Content x Dose	4	4.0535	1.013375	5.159**
Fat x Time x Dose	20	3.8623	.193115	0.983**
Fat x Temp. x Dose	4	.5936	.148400	0.755
Fat x Time x Temp. x Dose	20	3.9278	.196390	

* $P \leq 0.05$

** $P \leq 0.01$

and 5.0 megarads, respectively (Table II,c and Figure 6). Again the 0.5 megarad level of irradiation, followed closely by the 2.5 megarad level, was sufficient to retard any extensive microbial decomposition of the ground beef while still remaining low enough to eliminate the harsh irradiated odor and flavor. The 5.0 megarad level of irradiation adequately preserved the meat, however, the flavor change also produced was such that taste panel means were lower than that for the 0.0 megarad level when both storage temperatures were pooled. When considered independently the taste panel means for the ground beef stored at 0° F. were negatively related to irradiation level. This phenomenon occurred in each of the levels of maturity and yet it is not at all surprising due to the fact that meat will remain edible for a period of 10 weeks at 0° F. storage without the need of irradiation. On the other hand, the means presented in Table III,c indicated the preferred order of levels of irradiation for ground beef stored at 40° F. to be 0.5, 2.5, 5.0, 0.1 and 0.0 megarads, respectively. This sequence of irradiation level is due to the decreased keeping capabilities of the 40° F. temperature. A preference was shown for the more irradiated samples under this storage temperature. The radiation tends to preserve the meat when temperature does not (Figure 7).

As a means of analyzing maturity data the three maturity levels were compared. The taste panel means from the 6, 12 and 24 month old animals are presented in Tables G and H (Appendix). An analysis of variance for these data is shown in Table VI. From this analysis animal maturity was found to be significant at the 1 per cent level. Animal maturity means presented in Table VII revealed the irradiated ground beef from the 12 month old animals to be the most preferred level of animal maturity.

TABLE VI

ANALYSIS OF VARIANCE - ANALYTICAL TASTE PANEL SCORES OF GROUND BEEF FROM ANIMALS 6, 12 and 24 MONTH OLD AT TIME OF SLAUGHTER

Source	d/f	SS	MS	F
Total	359	110.4230		
Fat Content	1	.5242	.524200	16.402**
Storage Time	5	6.1277	1.225540	38.346**
Fat Content x Storage Time	5	.9455	.189100	5.917**
Storage Temperature	1	23.1778	23.177800	725.210**
Storage Temp. x Storage Time	5	4.9512	.990240	30.984**
Fat Content x Storage Temp.	1	.1589	.158900	4.972*
Fat x Time x Temperature	5	.1647	.032940	1.031
Irradiation Dose	4	7.5989	1.899725	59.440**
Storage Time x Dose	20	7.7151	.385755	12.070**
Storage Temp. x Dose	4	36.7969	9.199225	287.834**
Time x Temp. x Dose	20	8.8883	.444415	13.905**
Fat Content x Irrad. Dose	4	.8427	.210675	6.592
Fat x Time x Dose	20	.7171	.035855	1.122
Fat x Temp. x Dose	4	.0252	.006300	0.197
Fat x Time x Temp. x Dose	20	.4493	.022465	0.703
Maturity	2	.9661	.483050	15.114**
Storage Time x Maturity	10	.5009	.050090	1.567
Storage Temp. x Maturity	2	.2880	.144000	4.506*
Irrad. Dose x Maturity	8	.2945	.036813	1.152
Time x Temp. x Maturity	10	.8795	.087950	2.752*
Time x Dose x Maturity	40	1.8582	.046455	1.453
Temp. x Dose x Maturity	8	.0954	.011925	0.373
Time x Temp. x Dose x Maturity	40	1.4411	.036028	1.127
Fat Content x Maturity	2	.2804	.140200	4.387*
Fat x Time x Maturity	10	.7456	.074560	2.223*
Fat x Temp. x Maturity	2	.4163	.208150	6.513**
Fat x Dose x Maturity	8	.3100	.038750	1.212
Fat x Time x Temp. x Maturity	10	.4192	.041920	1.312
Fat x Time x Dose x Maturity	40	1.4141	.035353	1.106
Fat x Temp. x Dose x Maturity	8	.1518	.018975	0.594
Fat x Time x Temp. x Dose x Maturity	40	1.2784	.031960	

* $P \leq 0.05$
** $P \leq 0.01$

This maturity level was followed in preference by the 24 and 6 month old animals, respectively. This is illustrated by Figure 8.

TABLE VII

FLAVOR MEAN SCORES FROM ANIMALS 6, 12 AND 24 MONTHS OLD AT TIME OF SLAUGHTER

Maturity	Mean
6 Mo. Old Animals	4.47
12 Mo. Old Animals	4.77
24 Mo. Old Animals	4.67
Mean	4.66

The review of literature indicated veal to be less adversely affected by irradiation than beef, however, results presented in Table VII do not parallel these findings. Although the 6 month old animals would be classified as calf rather than veal this still does not explain the reason why irradiated ground beef from the 6 month old animals was the least preferred. One mode of explanation might be the fat content of ground beef from the 6 month old animals. The fat content of the high fat ground beef may have been such that it was more objectionable than the effects of irradiation. The proximate analyses regarding the high fat content of ground beef from the 6, 12 and 24 month old animals were 27.30, 25.00 and 31.78 per cent, respectively. The decrease in taste preference due strictly to the high fat content may explain why meat from the 12 month old animals was preferred to that of the 6 month old animals, but it does not explain why meat from the 24 month old animals was preferred over that from the 6 month old animals.

The three levels of animal maturity were pooled to investigate

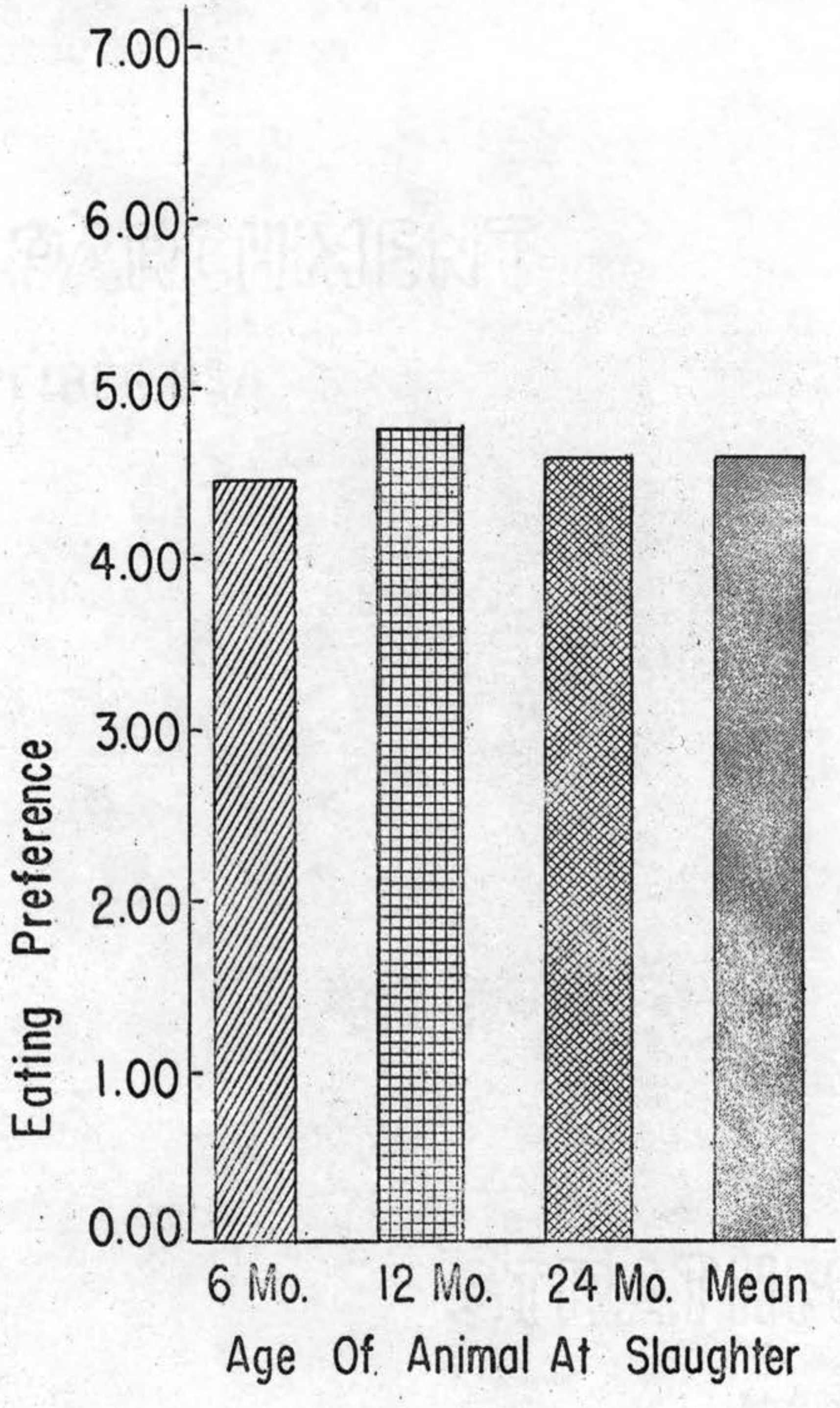


Figure 8. Taste panel means of irradiated ground beef as influenced by animals of different maturity levels.

their effect upon the other variables. The analysis of variance presented in Table VI revealed storage period, storage temperature and irradiation level to be significant at the 1 per cent level. Table II,a contains the means for the storage period for each of the maturity levels. A study of the data obtained from this investigation indicated a relatively constant decrease in taste panel means up to 8 weeks of storage at the end of which time continued storage, to 10 weeks, showed an increase in preference scores. A review of the analysis from each of the maturity levels indicated approximately the same findings. These data are illustrated graphically in Figure 4. The increase in ground beef preference during progressive storage appeared to be related to the loss of the irradiated odor and flavor. During the preparation for cooking, it was noted that the ground beef patties lost their irradiated odor intensity as the storage period progressed. A decrease of irradiation flavor intensity then too might occur.

The storage temperature means presented in Table II,b again indicated, as shown with each of the maturity levels, the 0° F. storage temperature to be preferred to that of 40° F. storage. These results would be expected because of the preservative action exhibited by 0° F. storage even without the aid of radiation. Ground beef stored at 0° F. that had been exposed to no or little radiation would naturally be preferred to samples with the same radiation and stored at 40° F. An increase in the irradiation of ground beef stored at 40° F. was necessary as a method of preservation for such storage conditions. The effect of storage temperature is illustrated in Figure 5.

Irradiation level means for the pooled maturity analysis are presented in Tables II,c and III,d. The level of irradiation in order of taste preference are as follows: 0.5, 2.5, 0.0, 0.1 and 5.0 megarad levels, respectively. Taste panel scores of ground beef stored at 0 and 40° F. illustrated an irradiation level preference sequence which remained unchanged regardless of the maturity level. Tables III,a; III,b and III,c indicated the sequence of irradiation preference for the 0° F. storage temperature to be 0.0, 0.1, 0.5, 2.5 and 5.0 megarads, respectively. These occurrences are illustrated in Figures 6 and 7. Because the 0° F. storage temperature was sufficient to preserve the ground beef alone any increase in irradiation, which produced adverse effects, decreased the taste panel means. However, when the ground beef was stored at 40° F. the 0.5 megarad level was of adequate concentration to provide some preservation effects while still not being detrimental to the organoleptic qualities of the ground beef. This level of irradiation was followed closely by the 2.5 and 5.0 megarad levels indicating the higher levels of irradiation are less objectionable than the ground beef irradiated at the 0.0 megarad level when stored at 40° F.

II. Meat Composition

Numerous reports have been made with reference to the effect of fat content upon the acceptability of irradiated ground beef. A review of the literature pointed out the belief that fat of sufficient quantities decreased or alleviated, in part at least, the irradiated flavor and odor of ground beef subjected to such treatment.

A summary of taste panel means for fat content are presented in Table VIII. It was interesting to note that ground beef of low fat content, in every maturity level, exhibited a higher mean than that of ground beef with a higher fat content. The fat content mean values were

TABLE VIII

FLAVOR MEAN SCORES FROM 6, 12 AND 24 MONTH OLD ANIMALS OF TWO LEVELS OF FAT

Animal Maturity	Levels of Fat		
	Low	High	Mean
6 Mo. Old Animals	4.60	4.33	4.47
12 Mo. Old Animals	5.02	4.52	4.77
24 Mo. Old Animals	4.81	4.53	4.67
Mean	4.81	4.46	4.64

the highest for the 12 month old animals and lowest for the 6 month old animals regardless of whether low or high fat content was considered. However, from the analysis of variance for each of the respective maturity levels and from the overall analysis only the 12 month old and the overall analysis (6, 12 and 24 month old animals) revealed significant differences between the two levels of fat content. No significant difference was shown to exist between the two fat levels for the 6 and 24 month old animals. Figure 9 illustrates these results graphically.

The fat percentages for each fat level from the 6, 12 and 24 month old animals are presented in Table IX. The fat content of the ground beef from each maturity level is not constant due to human estimation during de-fatting, however, the differences in percentage of fat

TABLE IX

PER CENT FAT IN LOW AND HIGH FAT GROUND BEEF FROM 6, 12 AND 24 MONTH OLD ANIMALS

Level of Fat	Animal Maturity		
	6 Mo. Old	12 Mo. Old	24 Mo. Old
Low Fat	6.87	10.53	6.79
High Fat	27.30	25.00	31.78

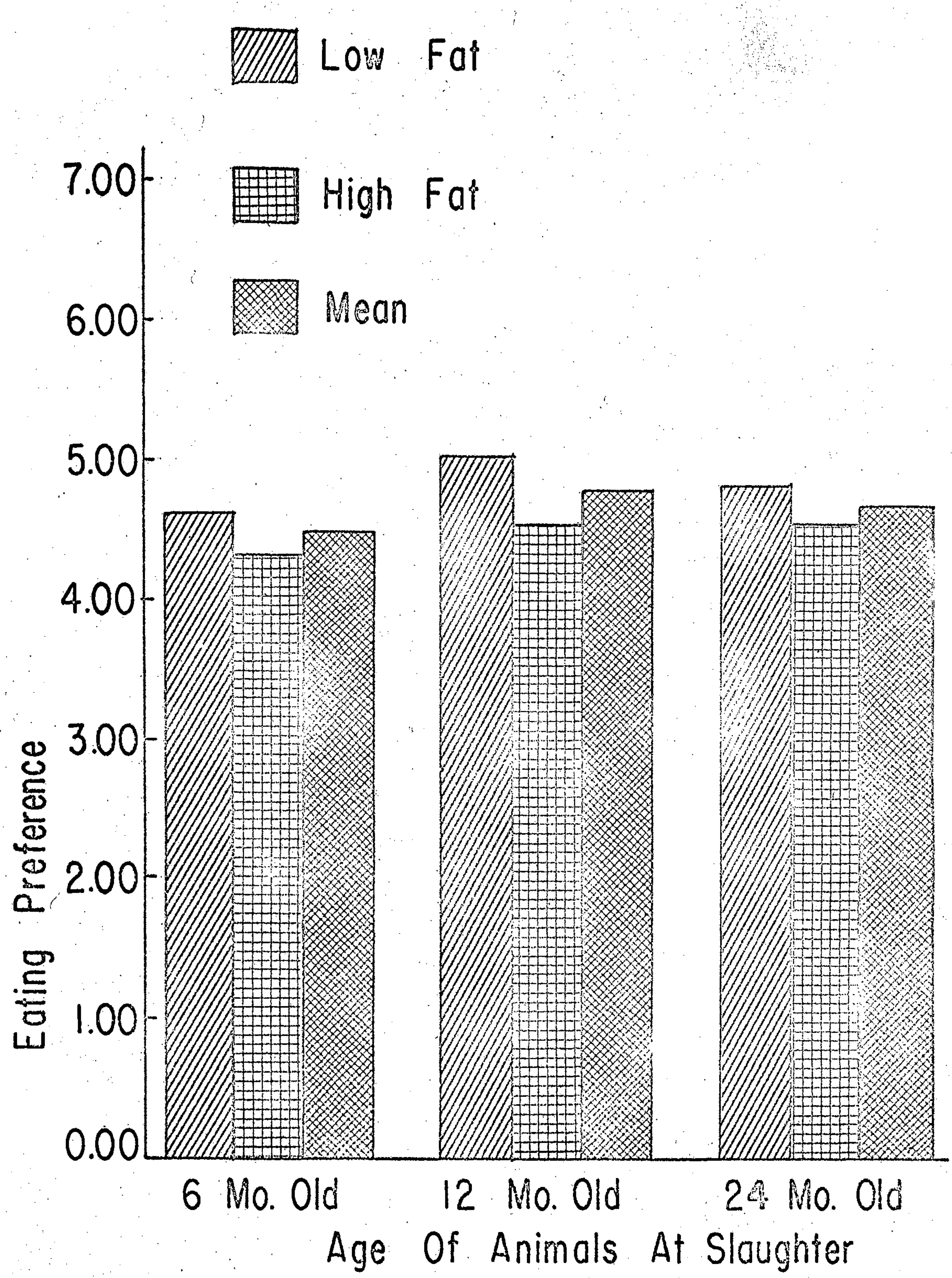


Figure 9. Taste panel means of irradiated ground beef from animals of different maturity as influenced by fat content.

are not extensive. From the study of fat percentages above no adequate explanation can be given as to the reason behind the results obtained in this study.

The interaction between fat content and storage time was revealed to be significant at the 1 per cent level for the 6 month old animals as shown in Table I. The taste panel means for the lean ground beef (Table X,a) were variable throughout storage, however, a trend of decreasing preference was evident through 8 weeks of storage after which time preference remained relatively uniform. The taste panel means of high fat ground beef gradually decreased as the storage period progressed up to 8 weeks also, however, an increase in preference did occur between the 8 and 10 weeks of storage. Although differences were observable during the first part of storage between lean and fat samples, upon completion of 10 weeks of storage these differences had diminished considerably as seen in Figure 10.

Table XI,a contains the means of ground beef of low and high fat contents stored at 0 and 40° F. which were shown to be highly significant. A study of the means presented in this table revealed the 0° F. storage temperature was preferred to that of 40° F. This is also shown in Figure 11.

The fat content and irradiation level interaction was found to be highly significant. Taste panel means are presented in Table XII,a as well as shown in Figure 12. Regardless of the fat content the 0.5 megarad level of irradiation exhibited the least discriminated preference scores, however, the highest taste panel mean was slightly above "neither like nor dislike" rating. It is interesting to note that the high fat content ground beef was preferred to the low level of fat when the

TABLE X

FAT CONTENT AND STORAGE PERIOD MEANS FOR THE RESPECTIVE MATURITY LEVELS

a
6 Month Old Animals

	Storage Period (Weeks)						
Fat Level	0	2	4	6	8	10	Mean
Low Fat	5.35	4.44	5.54	4.22	3.98	4.02	4.59
High Fat	4.75	4.44	4.33	4.17	3.96	4.40	4.34
Mean	5.05	4.44	4.94	4.20	3.97	4.21	4.47

b
12 Month Old Animals

	Storage Period (Weeks)						
Fat Level	0	2	4	6	8	10	Mean
Low Fat	5.83	5.83	5.19	4.57	4.43	4.26	5.02
High Fat	5.28	4.26	4.36	4.58	4.28	4.48	4.54
Mean	5.56	5.05	4.78	4.58	4.36	4.37	4.78

c
24 Month Old Animals

	Storage Period (Weeks)						
Fat Level	0	2	4	6	8	10	Mean
Low Fat	6.00	5.57	4.22	4.17	4.48	4.43	4.81
High Fat	5.19	4.84	4.27	4.42	4.19	4.22	4.52
Mean	5.60	5.21	4.25	4.30	4.34	4.33	4.67

d
6, 12 and 24 Month Old Animals

	Storage Period (Weeks)						
Fat Level	0	2	4	6	8	10	Mean
Low Fat	5.73	5.28	4.98	4.32	4.30	4.24	4.81
High Fat	5.07	4.51	4.32	4.39	4.13	4.37	4.46
Mean	5.40	4.90	4.65	4.36	4.22	4.31	4.64

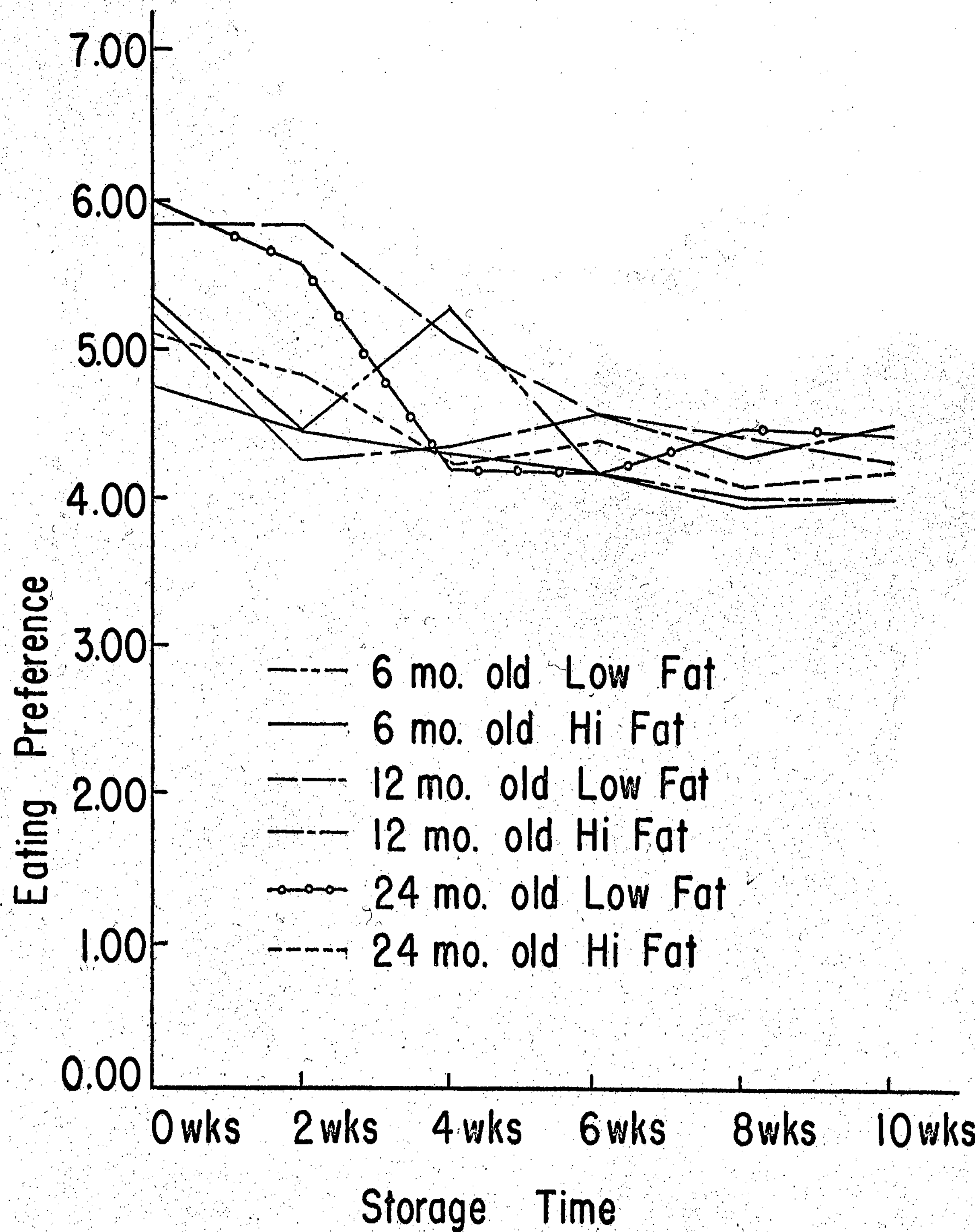


Figure 10. Taste panel means of irradiated ground beef from animals of different maturity as influenced by fat content and storage period.

TABLE XI

FAT CONTENT AND STORAGE TEMPERATURE MEANS FOR THE RESPECTIVE MATURITY LEVELS

a
6 Month Old Animals

	Storage Temperature		
Fat Level	0° F.	40° F.	Mean
Low Fat	5.46	3.74	4.60
High Fat	5.02	3.64	4.33
Mean	5.24	3.69	4.47

b
12 Month Old Animals

	Storage Temperature		
Fat Level	0° F.	40° F.	Mean
Low Fat	5.82	4.22	5.02
High Fat	5.45	3.58	4.52
Mean	5.64	3.90	4.77

c
24 Month Old Animals

	Storage Temperature		
Fat Level	0° F.	40° F.	Mean
Low Fat	5.62	4.00	4.81
High Fat	5.13	3.93	4.53
Mean	5.38	3.97	4.67

d
6, 12 and 24 Month Old Animals

	Storage Temperature		
Fat Level	0° F.	40° F.	Mean
Low Fat	5.63	3.99	4.81
High Fat	5.20	3.72	4.46
Mean	5.42	3.86	4.64

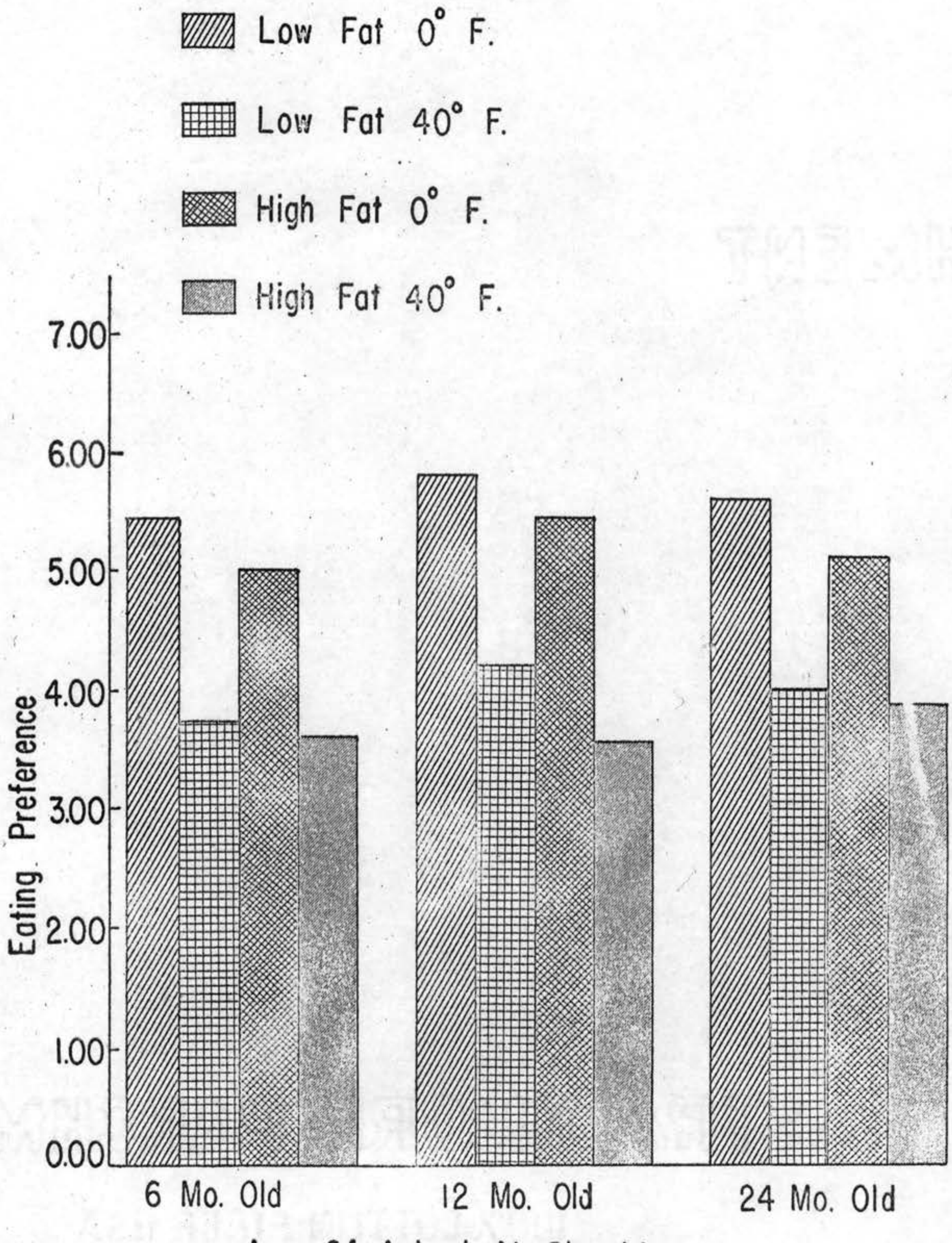


Figure 11. Taste panel means of irradiated ground beef from animals of different maturity as influenced by fat content and storage temperature.

TABLE XII

FAT CONTENT AND RADIATION LEVEL MEANS FOR THE RESPECTIVE MATURITY LEVELS

a
6 Month Old Animals

	Radiation - (Megarads)					
Fat Level	5.0	2.5	0.5	0.1	0.0	Mean
Low Fat	3.58	4.36	5.41	4.29	4.38	4.40
High Fat	4.11	4.77	5.19	3.68	3.88	4.33
Mean	3.85	4.57	5.30	3.99	4.13	4.37

b
12 Month Old Animals

	Radiation - (Megarads)					
Fat Level	5.0	2.5	0.5	0.1	0.0	Mean
Low Fat	4.75	4.95	5.84	4.91	4.55	5.00
High Fat	4.23	4.67	5.36	4.13	4.19	4.52
Mean	4.49	4.81	5.60	4.52	4.37	4.76

c
24 Month Old Animals

	Radiation - (Megarads)					
Fat Level	5.0	2.5	0.5	0.1	0.0	Mean
Low Fat	4.05	4.48	5.49	4.74	4.73	4.70
High Fat	4.37	4.63	5.41	4.08	4.24	4.55
Mean	4.21	4.56	5.45	4.41	4.49	4.63

d
6, 12 and 24 Month Old Animals

	Radiation - (Megarads)					
Fat Level	5.0	2.5	0.5	0.1	0.0	Mean
Low Fat	4.13	4.73	5.58	4.65	4.55	4.70
High Fat	4.24	4.69	5.32	3.96	4.10	4.47
Mean	4.18	4.71	5.45	4.26	4.33	4.59

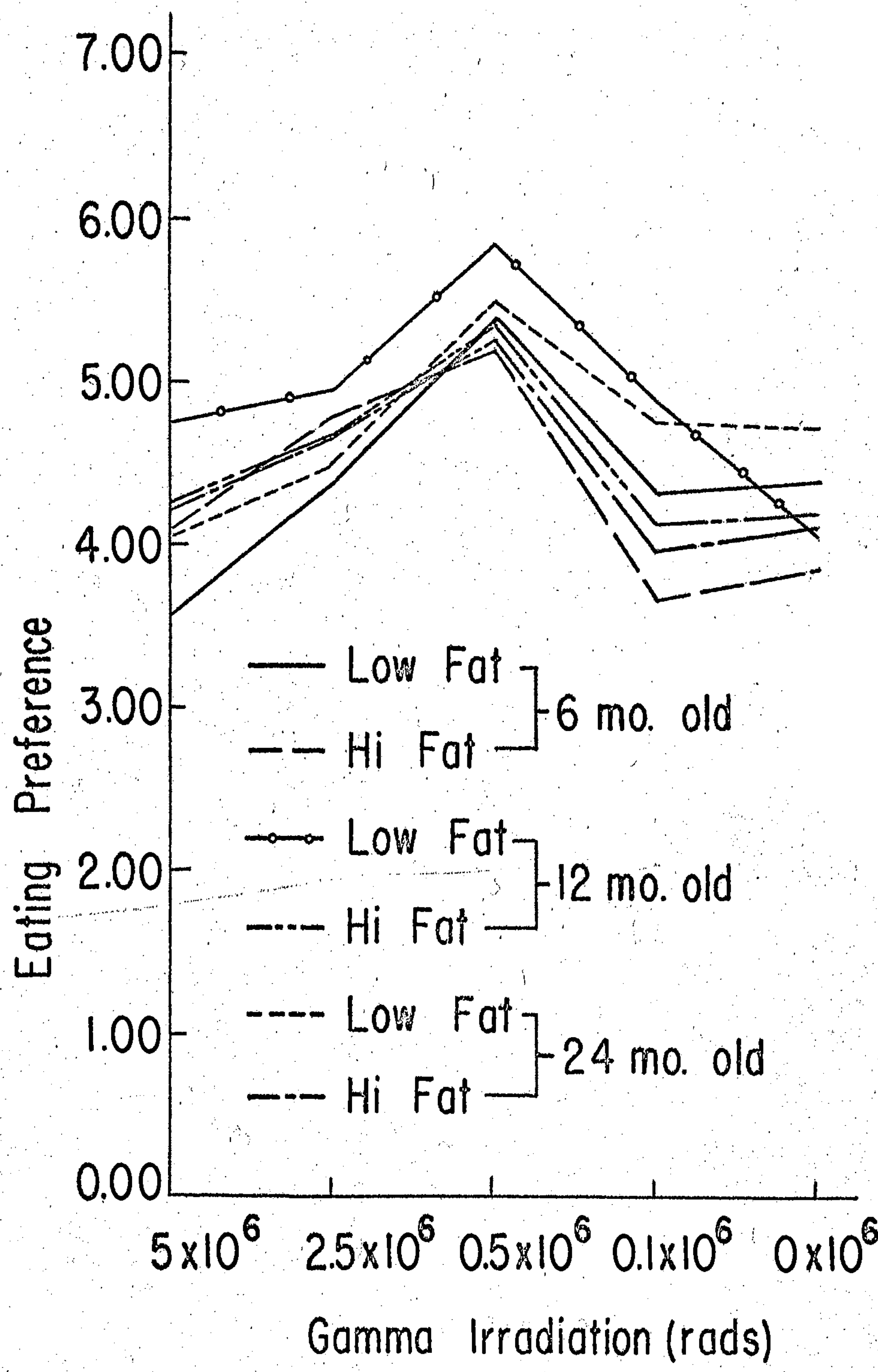


Figure 12. Taste panel means of irradiated ground beef from animals of different maturity as influenced by fat content and irradiation level.

higher irradiation levels were used, i.e. the 2.5 and 5.0 megarads. At the lower levels of irradiation the low fat ground beef was preferred. This may be explained, in part, by recalling the results reported in the literature. It is believed by some that the water soluble proteins are the most irradiation-sensitive component of meat. Therefore, irradiated meat containing large amounts of these proteins or meat being exposed to larger doses of irradiation will produce a less desirable product. However, if large amounts of fat were added to reduce the total amount of these water soluble proteins present per volumn or if the irradiation levels were lowered this would tend to increase the preference scores for the product. It must be kept in mind, however, that high levels of fat may be more objectionable than the irradiation.

A study of the data obtained from the 12 month old animals indicated results similar to that obtained from the 6 month old animals. The interaction between fat content and storage period was significant at the 5 per cent level for the 12 month old animals. The means for this interaction are recorded in Table X,b and illustrated in Figure 10. Ground beef of low fat content was preferred to that of high fat content during the period prior to 6 weeks storage. Taste panel means were variable throughout the remainder of the storage period, however, high fat ground beef was preferred over that of low fat at 10 weeks storage.

No significant differences were found to exist between the fat content of the meat and storage temperature. It was noted, however, that the means for ground beef of low fat content were higher than those for high fat as shown in Table XI,b and Figure 11.

No significant differences were observed between fat content and irradiation level. Means, however, indicated a preference for the low fat ground beef regardless of the level of irradiation (Table XII,b). This is illustrated in Figure 12. The order of irradiation level preference for the low fat content was 0.5, 2.5, 0.1, 5.0 and 0.0 megarads, respectively, which is not the same sequence of preference expressed by the 6 month old animals. On the other hand, the sequence of irradiation level preference for the high fat content ground beef, being 0.5, 2.5, 5.0, 0.0 and 0.1 megarads, respectively, was exactly as that expressed by the high fat content ground beef of the 6 and 24 month old animals.

The interaction between fat content and storage period was found to be significant at the 5 per cent level for the 24 month old animals. The means presented in Table X,c indicated variable data towards the latter 4 weeks of storage for both fat levels. However, a decrease in preference did result as storage progressed. The data from this maturity level indicated no noticeable increase in preference at 10 weeks of storage. Figure 10 illustrated these data graphically.

Fat content and storage temperature interaction was also significant at the 5 per cent level as shown in Table V. Again the taste panel means presented in Table XI,a indicated the 0° F. storage temperature to be preferred regardless of the fat content of the ground beef. Figure 11 illustrated that the difference in preference is less between the low and high fat levels when the ground beef was stored at 40° F. than when stored at 0° F.

The relationship between fat content and irradiation level was found to be significant at the 1 per cent level. Taste panel means presented in Table XII,a revealed values similar to those for the 6 month old animals. The low fat ground beef revealed the 0.5 megarad level of irradiation to be the most preferred while the 5.0 megarad level was the least preferred which was in agreement with the 6 month old animals data. However, the preference sequence of the other three levels of irradiation varied from that of the 6 month old animals, but the change of sequence was slight. The high fat ground beef revealed the level of irradiation preference to be exactly the sequence as that of the 6 month old animals. Figure 12 reminds us that the irradiation-sensitive water soluble protein explanation may also be applied to these data of this maturity level.

An overall analysis of variance for the 6, 12 and 24 month old animals is presented in Table VI. The analysis indicated the interactions between fat content and storage period as well as that of fat content and storage temperature to be significant at the 1 and 5 per cent levels, respectively. On the other hand, fat content and irradiation level interaction was not significant at the 5 per cent level. The means of the fat content and storage period interaction are presented in Table X,d. A study of these data revealed a preference for low fat ground beef during storage except at the 6 and 10 weeks storage periods at which storage periods the high fat ground beef was preferred. However, the preference advantage was so small for the high fat ground beef at these storage periods no importance was given to it. From the overall analysis it can be generally concluded that ground beef of low fat content is preferred to that of high fat during the storage period.

A study of the taste panel means from the overall analysis for the fat content and storage temperature interaction indicated 0° F. storage temperature was preferred to that of 40° F. regardless of the fat content. The means for this interaction are presented in Table XI,d. This trend has been shown to occur for each of the respective maturity levels throughout this study. It should be noted, however, that the difference between taste panel means of low fat ground beef and those for high fat ground beef are not extreme. On the contrary these are only slight differences which range on the taste panel score sheets from approximately "dislike slightly" to "neither like nor dislike."

An overall analysis of the interaction between fat content and irradiation level revealed that the 5.0 megarad level of irradiation is the only dosage at which the high fat ground beef was preferred to the low fat samples. The means presented in Table XII,d indicated that the low fat ground beef was preferred to the high fat ground beef at all of the other levels of irradiation. It is thought that the high fat ground beef contained a smaller quantity of the water soluble proteins, which upon subjection to high levels of irradiation produces the characteristic irradiated meat flavors. In evaluating these data it should be noted, however, that this test was not significant at the 5 per cent level.

SUMMARY

The acceptability of irradiated ground beef, as evaluated by an analytical taste panel, depends upon how closely related the product is to those organoleptic qualities sought in fresh beef. The effect of irradiation upon fresh beef is one of altering these desirable attributes of meat quality. It was therefore the purpose of this study to investigate the effects of animal maturity and fat content upon the acceptability of irradiated ground beef.

The effect of animal maturity upon the taste panel acceptability of irradiated ground beef was significant ($P < 0.01$). The means indicated a preference for the 12, 24 and 6 month old animals, respectively.

The difference due to the fat content of ground beef from the 6 and 24 month old animals was not significant, however, significance was exhibited by the 12 month old animals and the overall analysis of the three maturity levels ($P \leq 0.01$). Although the fat content of ground beef was not significant for the 6 and 24 month old animals it was evident that ground beef of low fat content was preferred over that of the high fat content.

The interaction between fat content and storage period was significant for each of the animal maturity levels. Regardless of the fat level, as the storage period progressed, taste panel means decreased. However, an increase in preference did result after 8 weeks of storage. Taste panel means were noticeably higher for low fat ground beef upon initial storage, but as storage progressed and upon completion of the storage period little detectable differences between low and high fat ground beef could be seen.

The fat content and storage temperature interaction was significant for all maturity levels except the 12 month old animals. The 0° F. storage temperature was preferred to that of 40° F. regardless of the fat content. Also the low fat ground beef was preferred to that of high fat regardless of the storage temperature.

Also found to be significant was the interaction between fat content and irradiation level for the 6 and 24 month old animals ($P < 0.01$). This interaction was not significant for the 12 month old animals and the overall analysis. The 0.5 megarad level of irradiation was the most preferred level regardless of the fat content of the meat. Low fat ground beef revealed preference for the 0.5, 2.5, 5.0, 0.0 and 0.1 megarad levels of irradiation, respectively, regardless of the maturity levels.

Storage period, storage temperature and irradiation level were all significant for each of the three maturity levels ($P \leq 0.01$). Taste panel means generally decreased as the storage period progressed. However, the means did indicate improvement in flavor after 8 weeks of storage. The 0° F. storage temperature was preferred to that of 40° F. Taste panel preference decreased as the irradiation level increased when the ground beef was stored at 0° F., however, when stored at 40° F. the 0.5 megarad level of irradiation was the most preferred followed by the higher levels. The 0.0 and 0.1 megarad levels were unable to adequately preserve the ground beef stored at 40° F.

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APPENDIX

TABLE A

TASTE PANEL SCORES OF IRRADIATED GROUND BEEF OF LOW FAT CONTENT STORED AT 0° F. AND 40° F. FROM 6 MONTH OLD ANIMALS[1]

LOW FAT

0° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	3.91	2.90	3.92	3.50	3.55	4.67	3.74
2.5×10^6	4.00	4.40	4.75	3.86	4.27	5.34	4.44
0.5×10^6	5.36	6.30	6.17	5.86	6.55	5.42	5.94
0.1×10^6	6.10	6.70	6.42	6.50	6.27	7.17	6.53
Non-Irrad.	7.36	6.90	5.50	6.22	6.36	7.50	6.64
Totals	5.35	5.44	5.35	5.19	5.40	6.02	5.46

40° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	3.91	3.56	4.08	3.72	3.00	2.20	3.41
2.5×10^6	4.00	4.63	4.75	5.07	4.50	2.80	4.29
0.5×10^6	5.36	5.38	6.67	5.43	3.30	3.10	4.87
0.1×10^6	6.10	2.19	1.00	1.00	1.00	1.00	2.05
Non-Irrad.	7.36	1.38	1.00	1.00	1.00	1.00	2.12
Totals	5.35	3.43	3.50	3.25	2.56	2.02	3.74

[1]Taste panel scores are an average of 14 members.

TABLE B

TASTE PANEL SCORES OF IRRADIATED GROUND BEEF OF HIGH FAT CONTENT STORED AT 0° F. AND 40° F. FROM 6 MONTH OLD ANIMALS[1]

HIGH FAT

0° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	3.45	3.75	4.34	3.34	3.93	3.83	3.77
2.5×10^6	4.18	4.67	4.09	5.09	4.15	5.34	4.59
0.5×10^6	5.18	4.99	5.84	5.00	5.50	5.50	5.31
0.1×10^6	5.02	5.29	5.79	5.09	5.57	6.00	5.44
Non-Irrad.	5.97	5.77	5.71	5.33	6.07	6.83	5.93
Totals	4.76	4.89	4.97	4.77	5.05	5.50	5.02

40° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	3.45	5.34	4.42	4.70	4.10	4.70	4.45
2.5×10^6	4.18	4.92	5.25	5.60	4.50	4.70	4.95
0.5×10^6	5.18	4.50	6.09	5.50	3.90	5.10	5.04
0.1×10^6	5.02	2.50	1.00	1.00	1.00	1.00	1.92
Non-Irrad.	5.97	1.00	1.00	1.00	1.00	1.00	1.82
Totals	4.76	3.66	3.55	3.56	2.90	3.30	3.64

[1]Taste panel scores are an average of 14 members.

TABLE C

TASTE PANEL SCORES OF IRRADIATED GROUND BEEF OF LOW FAT CONTENT STORED AT 0° F. AND 40° F. FROM 12 MONTH OLD ANIMALS[1]

LOW FAT

0° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	4.93	5.60	5.06	5.00	3.76	3.13	4.58
2.5×10^6	5.53	5.20	4.63	4.07	5.06	4.13	4.77
0.5×10^6	6.07	7.00	7.19	5.73	5.47	5.60	6.18
0.1×10^6	5.80	7.07	7.63	6.67	7.24	5.67	6.68
Non-Irrad.	6.80	6.20	6.94	6.27	6.75	7.40	6.73
Totals	5.83	6.21	6.29	5.55	5.66	5.19	5.79

40° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	4.93	4.81	4.93	4.85	4.19	5.86	4.93
2.5×10^6	5.53	5.19	4.73	4.63	4.19	6.50	5.13
0.5×10^6	6.07	6.94	6.67	5.54	5.56	2.29	5.51
0.1×10^6	5.80	6.88	3.13	1.00	1.00	1.00	3.14
Non-Irrad.	6.80	3.44	1.00	1.00	1.00	1.00	2.37
Total	5.83	5.45	4.09	3.40	3.19	3.33	4.22

[1]Taste panel scores are an average of 14 members.

TABLE D

TASTE PANEL SCORES OF IRRADIATED GROUND BEEF OF HIGH FAT CONTENT STORED AT 0° F. AND 40° F. FROM 12 MONTH OLD ANIMALS[1]

HIGH FAT

0° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	4.50	3.97	4.19	5.85	3.92	4.00	4.41
2.5×10^6	5.21	4.21	4.31	5.25	4.20	4.60	4.63
0.5×10^6	5.64	5.21	5.13	5.05	6.47	5.93	5.58
0.1×10^6	6.29	5.47	6.81	5.80	6.27	6.33	6.16
Non-Irrad.	6.00	6.20	7.06	6.60	6.33	6.66	6.48
Totals	5.53	5.02	5.50	5.71	5.44	5.50	5.45

40° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	3.64	3.67	4.21	4.95	3.80	4.00	4.05
2.5×10^6	4.50	4.14	4.64	5.50	4.73	4.73	4.71
0.5×10^6	5.50	5.05	4.86	4.80	4.07	6.50	5.13
0.1×10^6	5.36	3.05	1.13	1.00	1.00	1.00	2.09
Non-Irrad.	5.64	1.57	1.25	1.00	1.00	1.00	1.91
Totals	4.93	3.50	3.22	3.45	2.92	3.45	3.58

[1]Taste panel scores are an average of 14 members.

TABLE E

TASTE PANEL SCORES OF IRRADIATED GROUND BEEF OF LOW FAT CONTENT STORED AT 0° F. AND 40° F. FROM 24 MONTH OLD ANIMALS[1]

LOW FAT

0° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	4.26	4.45	3.56	3.92	3.07	3.79	3.84
2.5×10^6	5.44	4.30	5.06	3.85	4.14	3.64	4.41
0.5×10^6	6.32	5.65	5.72	5.46	5.21	5.36	5.62
0.1×10^6	7.00	7.20	6.17	6.69	6.29	6.29	6.61
Non-Irrad.	7.01	7.00	6.44	6.54	6.93	7.21	6.86
Totals	6.00	5.62	5.39	5.29	5.13	5.26	5.46

40° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	4.26	4.27	3.50	3.77	5.00	4.80	4.27
2.5×10^6	5.44	4.45	3.80	4.00	4.38	5.30	4.56
0.5×10^6	6.32	5.00	5.10	4.23	5.58	5.90	5.36
0.1×10^6	7.00	4.73	1.70	1.77	1.00	1.00	2.87
Non-Irrad.	7.01	4.09	1.10	1.46	1.00	1.00	2.61
Totals	6.00	4.51	3.04	3.05	3.40	3.60	4.00

[1]Taste panel scores are an average of 14 members.

TABLE F

TASTE PANEL SCORES OF IRRADIATED GROUND BEEF OF HIGH FAT CONTENT STORED AT 0° F. AND 40° F. FROM 24 MONTH OLD ANIMALS[1]

HIGH FAT

0° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	4.64	3.75	3.57	3.86	3.64	3.56	3.83
2.5×10^6	4.19	4.60	4.26	4.15	4.00	4.37	4.27
0.5×10^6	5.29	5.35	4.94	6.00	5.86	5.70	5.52
0.1×10^6	5.84	6.53	4.94	6.21	4.93	5.54	5.67
Non-Irrad.	6.10	6.84	5.63	6.79	6.14	6.72	6.36
Totals	5.21	5.41	4.67	5.40	4.92	5.17	5.13

40° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	4.64	4.79	5.50	4.67	4.95	4.86	4.90
2.5×10^6	4.19	5.06	5.67	4.92	4.83	5.30	4.98
0.5×10^6	5.29	5.64	5.67	4.75	6.15	4.23	5.30
0.1×10^6	5.84	4.21	1.42	1.58	1.00	1.00	2.50
Non-Irrad.	6.10	1.67	1.67	1.25	1.00	1.00	2.11
Totals	5.21	4.27	3.98	3.43	3.47	3.28	3.93

[1]Taste panel scores are an average of 14 members.

TABLE G

TASTE PANEL SCORES OF IRRADIATED GROUND BEEF OF LOW FAT CONTENT STORED AT 0° F. AND 40° F. FROM 6, 12 AND 24 MONTH OLD ANIMALS[1]

LOW FAT

0° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	4.37	4.32	4.18	4.14	3.46	3.86	4.05
2.5×10^6	4.99	4.63	4.81	3.93	4.49	4.37	4.54
0.5×10^6	5.91	6.32	6.36	5.68	5.74	5.46	5.91
0.1×10^6	6.30	6.99	6.74	6.62	6.60	6.38	6.61
Non-Irrad.	7.06	6.70	6.29	6.34	6.68	7.37	6.74
Totals	5.72	5.78	5.68	5.34	5.39	5.49	5.57

40° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	4.37	4.21	4.17	4.11	4.06	4.29	4.20
2.5×10^6	4.99	4.76	4.43	4.57	4.36	4.87	4.66
0.5×10^6	5.92	5.77	6.15	5.07	4.81	3.76	5.25
0.1×10^6	6.30	4.60	1.94	1.26	1.00	1.00	2.68
Non-Irrad.	7.06	2.97	1.03	1.15	1.00	1.00	2.37
Totals	5.73	4.46	3.54	3.23	3.05	2.98	3.99

[1]Taste panel scores are an average of 14 members.

TABLE H

TASTE PANEL SCORES OF IRRADIATED GROUND BEEF OF HIGH FAT CONTENT STORED AT 0° F. AND 40° F. FROM 6, 12 AND 24 MONTH OLD ANIMALS[1]

HIGH FAT

0° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	4.20	3.82	4.03	4.35	3.83	3.80	4.00
2.5×10^6	4.53	4.49	4.22	4.83	4.12	4.77	4.50
0.5×10^6	5.37	5.20	5.30	5.35	5.94	5.71	5.48
0.1×10^6	5.72	5.76	5.85	5.70	5.59	5.96	5.76
Non-Irrad.	6.02	6.27	6.13	6.24	6.18	6.74	6.26
Totals	5.17	5.11	5.08	5.29	5.14	5.40	5.20

40° F. Storage Temperature

Radiation Dose Level	0 Wks.	2 Wks.	4 Wks.	6 Wks.	8 Wks.	10 Wks.	Total
5×10^6	3.91	4.60	4.71	4.77	4.28	4.52	4.47
2.5×10^6	4.29	4.71	5.19	5.34	4.69	4.91	4.87
0.5×10^6	5.32	5.06	5.54	5.02	4.71	5.28	5.16
0.1×10^6	5.41	3.25	1.18	1.19	1.00	1.00	2.17
Non-Irrad.	5.90	1.41	1.31	1.08	1.00	1.00	1.95
Totals	4.97	3.81	3.59	3.48	3.12	3.34	3.72

[1]Taste panel scores are an average of 14 members.

VITA

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